SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Digester Scum Control—Fuhrman

Accelerated Sludge Digestion—Morgan

High-Rate Sludge Digestion—Torpey

Laundry Waste Treatment—Wollner, et al

Deep-Water Disposal of Wastes—Orlob and Eldridge

Fungi in Polluted Water—Cooke

APRIL, 1954—VOL. 26, No. 4

Make Plans to Attend

27TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

NETHERLAND PLAZA HOTEL

CINCINNATI, OHIO

October 11-14, 1954

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

ACCELERATED SLUDGE DIGESTION NOW A FACT

at the Columbus, Ohio Sewage Treatment Works

CRP

CATALYTIC REDUCTION PROCESS

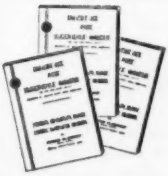
The Catalytic Reduction Process* has been installed at the Columbus, Ohio Sewage Treatment Works. The Process has increased digester capacity. For treatment plant expansion in the near future, it will not be necessary to build additional digesters. The Catalytic Reduction Process applied to one 70′ tank at the Columbus plant increased total digester capacity by the equivalent of three tanks.

This is possible because the Process completes biological sludge digestion with solids loading rates three to four times conventional past practice. The tank operating under the Process produces the required reduction of volatile solids, normal gas production, and a readily driable odorless sludge.

Originating in 1946, the Process was developed, tested and verified over six years on both laboratory and pilot plant scale. The results obtained in the pilot plant operation have been proven in full scale plant operation at the Columbus, Ohio installation.

The Catalytic Reduction Process is now available for consideration by consulting engineers for application on plants under design and for plants requiring expansion.

*The only proven Process for accelerating biological digestion. (Pat. app. for.)



Reprints of the paper by Professor P. F. Morgan on the development of this Process, and a paper by Mr. James H. Bladgett on the Columbus installation are available on request.

The Catalytic Reduction Process is offered through the Catalytic Reduction Co., Inc., a subsidiary of the Chicago Pump Company.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

622 DIVERSEY PARKWAY — **CHICAGO 14, ILLINOIS**

Flush Kleen, Screw-Feller, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

PRESIDENT

LOUIS J. FONTENELLI
Supervising Engineer
Rahway Valley Joint Meeting
Garwood, New Jersey

VICE-PRESIDENT

DAVID B. LEE
State Board of Health
P.O. Box 210
Jacksonville, Fla.

TREASURER

W. W. DEBERARD
Deputy Commissioner for Water
402 City Hall
Chicago 2, Illinois

EXECUTIVE SECRETARY-EDITOR

W. H. WISELY
325 Illinois Building
Champaign, Illinois

ADVISORY EDITOR

F. W. MOHLMAN
Director of Laboratories
The Sanitary District of Chicago
910 S. Michigan Ave.
Chicago, Illinois

DIRECTORS

Alabama: J. C. CLARKE (1954)
Arizona: LEIGH O. GARDNER (1955)
Arkansas: GLEN T. KELLOGG (1955)
California: F. G. NELSON (1956)
Canada: NICOL MACNICOL (1955)
Central States: W. D. HATFIELD (1954)
Dakota: R. J. STAFF (1955)
Federal: L. B. DWORSKY (1956)
Florida: J. E. KIKER, JR. (1956)
Georgia: C. E. DRUMMOND (1956)
Germany: F. SIERP (1956)
Inst. San. Eng. (Eng.): W. F. BROWN (1956)
Inst. Sew. Pur. (Eng.): W. F. FREEBORN (1956)
Iowa: H. S. SMITH (1956)
Kansas: G. E. MAU (1954)
Kentucky-Tennessee: F. W. KITTRELL (1955)
Louisiana: J. J. HOLTGREVE (1955)
Maryland-Delaware: W. M. BINGLEY (1954)
Michigan: CLYDE L. PALMER (1955)
Missouri: W. G. RIDDLE (1954)
Montana: H. OWEN (1956)
Nebraska: T. A. FILIPI (1955)
New England: W. H. BROWN, JR. (1954)
New Jersey: HENRY VAN DER VLIET (1954)
New York: W. H. LARKIN (1954)
North Carolina: P. D. DAVIS (1955)
Ohio: T. C. SCHAETZLE (1954)
Oklahoma: C. E. MOUTREY (1956)
Pacific Northwest: E. C. JENSEN (1956)
Pennsylvania: HOWARD T. REUNING (1955)
Puerto Rico: L. R. ROBLES (1956)
Rocky Mountain: C. G. CALDWELL (1954)
South Carolina: T. E. ROBERTSON, JR. (1955)
Sweden: NILS WESTBERG (1956)
Switzerland: EDUARD HOLINGER (1955)
Texas: E. W. STEEL (1954)
Virginia: B. L. STROTHER (1956)
West Virginia: R. F. ROCHELEAUX (1956)
At Large: R. G. TYLER (1954)
At Large: KERWIN L. MICK (1955)
At Large: V. MACKENZIE (1956)
W. and S. Wks. Mfgrs.: R. S. RANKIN (1954)
W. and S. Wks. Mfgrs.: HARRY E. SCHLENZ (1955)
W. and S. Wks. Mfgrs.: W. A. HARDENBERGH (1956)
Ex-Officio: E. SHERMAN CHASE
Ex-Officio: M. M. COHN
Ex-Officio: H. W. STREETER
Ex-Officio: F. W. GILCREAS
Ex-Officio: H. HEUKELEKIAN
Ex-Officio: W. J. ORCHARD
Ex-Officio: G. P. EDWARDS

SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE

Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States $1.00 each; Foreign, $1.25 each.

CLAIMS

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

MAILING PERMIT

Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE

Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

Builders News

B·I·F

Meters and controls engineered specifically for water, sewage, and waste plants . . . proven in thousands of installations.

INSTRUMENTATION NEWS

Chlorinating Equipment
•
Main line water meters
•
Sludge and waste flow meters
•
Remote metering equipment, electric, pneumatic
•
Automatic, flow proportional chemical feeder control
•
Filter operating tables and gauges
•
Wheeler filter bottoms
•
Automatic filter control
•
Pump controls, automatic, supervisory
•
Water level controllers, recorders

Chronoflo electric telemeter for remote metering . . . saves time, saves steps

Write for detailed bulletins

TECHNICAL NEWS

Engineering information on flow meters and controls
Industrial waste treatment guide

Add your name to our mailing list

MAINTENANCE NEWS

Nationwide service help
New preventive maintenance service plan —

Send for complete details

For up-to-the-minute information on the latest in meters and controls, address Builders-Providence, Inc. (Division of B-I-F Industries, Inc.), 368 Harris Ave., Providence 1, Rhode Island.

BUILDERS-PROVIDENCE

PIONEERS IN METERS AND CONTROLS

FSIWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
ALEX O. TAYLOR, *Secretary*
Box 69
Alabama Polytechnic Institute
Auburn, Alabama

Arizona Sewage and Water Works Assn.*
M. V. ELLIS, *Sec.-Treas.*
46 Encanto Blvd.
Phoenix, Ariz.

Arkansas Water and Sewage Conf.*
DR. HARRISON HALE, *Sec.-Treas.*
c/o Southern State College
Magnolia, Ark.

California Sewage and Industrial Wastes Assn.
SAM A. WEED, *Sec.-Treas.*
Room 315, City Hall, Oakland 18, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Ontario Dept. of Health
Parliament Bldgs.
Toronto 8, Ontario, Canada

Central States Sewage and Industrial Wastes Assn.
A. PAUL TROEMPER, *Sec.-Treas.*
2029 Bates Avenue
Springfield, Ill.

Dakota Water and Sewage Works Conf.

*North Dakota Section**
JEROME H. SVORE, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.

*South Dakota Section**
CHARLES E. CARL, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health, Pierre, S. Dak.

Federal Sewage Research Assn.
LLOYD W. GEBHARD, *Sec.-Treas.*
Rm. 4220, Health, Education & Welfare Bldg., So.,
Washington 25, D. C.

Florida Sewage and Industrial Wastes Assn.
DONALD P. SCHIESSWOHL, *Sec.-Treas.*
P. O. Box 210
Jacksonville 1, Fla.

Georgia Water and Sewage Assn.*
A. T. STOREY, *Sec.-Treas.*
1210 Hemphill Ave., N.W.
Atlanta, Ga.

(Germany) Abwassertechnische Vereinigung
OTTO PALLASCH, *Sec.-Treas.*
Theaterstrasse 24,
Bonn, Germany

Institute of Sewage Purification
W. F. FREEBORN, *Sec.*
34 Cardinal's Walk,
Hampton-on-Thames, Middlesex, England

Institution of Sanitary Engineers
ERNEST V. BALSOM, *Secretary*
118 Victoria St.
Westminster, S. W. 1, London, England

Iowa Sewage Works Assn.
L. F. SKORCZESKI, *Sec.-Treas.*
207 South 15th Ave.
Marshalltown, Iowa

Kansas Sewage and Industrial Wastes Assn.
DWIGHT F. METZLER, *Sec.-Treas.*
c/o State Board of Health
Marvin Hall, Room 2
University of Kansas, Lawrence, Kans.

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
R. PAUL FARRELL, *Sec.-Treas.*
420 Sixth Ave., N., Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
GEORGE H. WEST, *Sec.-Treas.*
P. O. Box 15, Water Dept., Lake Charles, La.

* Sewage Works Section.

Maryland-Delaware Water and Sewerage Assn.*
W. M. BINGLEY, *Sec.-Treas.*
2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334, Admin. Bldg., Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
c/o State Office Bldg., Sixth Floor
Jefferson City, Mo.

Montana Sewage and Industrial Wastes Assn.
HARVEY W. TAYLOR, *Sec.-Treas.*
Morrison & Maierle Inc.
Helena, Montana

Nebraska Sewage and Industrial Wastes Assn.
PAUL W. MOUSEL, *Secretary-Treasurer*
602 West B Street, McCook, Nebr.

New England Sewage and Industrial Wastes Assn.
STEPHEN M. HURLEY, JR., *Sec.-Treas.*
c/o State Dept. of Health
331 State Office Bldg., Providence, R. I.

New Jersey Sewage and Industrial Wastes Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 766, Manville, N. J.

New York Sewage and Industrial Wastes Assn.
RALPH C. SWEENEY, *Secretary*
c/o State Dept. of Health
21 N. Broadway, White Plains, N. Y.

North Carolina Sewage and Industrial Waste Assn.
E. C. HUBBARD, *Sec.-Treas.*
State Board of Health, Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conf.
WARD E. CONRAD, *Sec.-Treas.*
301 Ohio Depts. Bldg., Columbus 15, Ohio

Oklahoma Water, Sewage and Industrial Wastes Conf.*
H. J. DARCEY, *Sec.-Treas.*
State Dept. of Health, Oklahoma City 5, Okla.

Pacific Northwest Sewage and Industrial Wastes Assn.
WALTER W. SAXTON, *Sec.-Treas.*
408 Old Capitol Bldg.
Olympia, Wash.

Pennsylvania Sewage and Industrial Wastes Assn.
B. S. BUSH, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
Kirby Health Center, Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Assn.
ROBERT J. AULD, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2832, San Juan 12, Puerto Rico

Rocky Mountain Sewage Works Assn.
C. E. HARNESS, *Sec.-Treas.*
376 City and County Bldg., Denver, Colorado

South Carolina Water and Sewage Works Assn.*
W. T. LINTON, *Sec.-Treas.*
Wade Hampton Bldg., Columbia, S. C.

(Sweden) Föreningen För Vattenhygien
Erik Jonsson, *Secretary*
Box 5038, Stockholm 5, Sweden

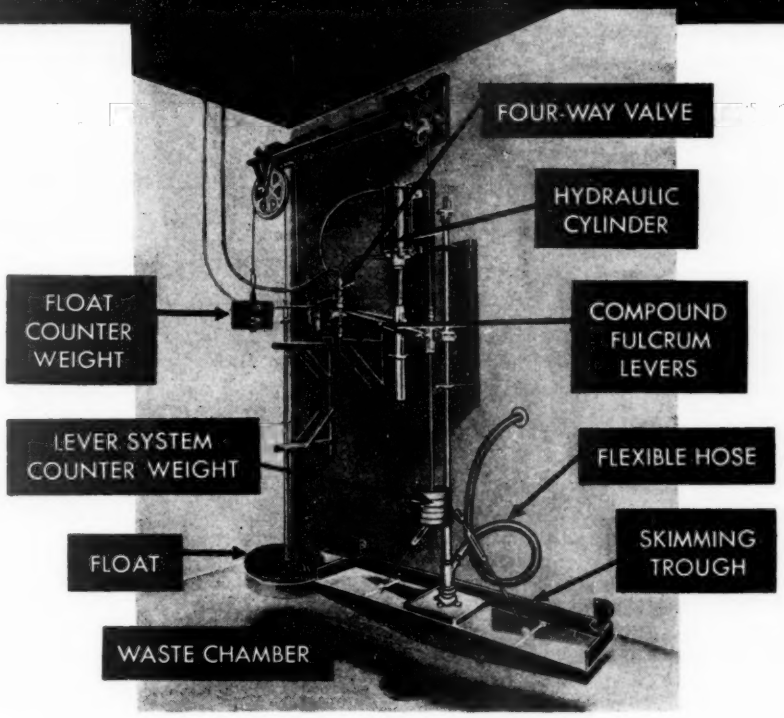
(Switzerland) Verband Schweizerischer Abwasserfachleute
EDUARD HOLINGER, *Treasurer*
Spitzackerstrasse 17, Liestal, Switzerland

Texas Water and Sewage Works Assn.*
V. M. EHLERS, *Sec.-Treas.*
501 W. 33rd St., Austin, Tex.

Virginia Industrial Wastes and Sewage Works Assn.
J. L. HAMRICK, JR., *Sec.-Treas.*
415 W. Franklin St., Richmond 20, Va.

West Virginia Sewage and Industrial Wastes Assn.
GLEN O. FORTNEY, *Sec.-Treas.*
State Dept. of Health, Charleston, W. Va.

STOP OILY-WASTE POLLUTION



Recover Valuable Oil!

The new Simplex Oil Skimmer reclaims oil that is ordinarily discharged along with other trade wastes. It can quickly pay for itself in three ways . . . recover valuable oil, conserve water, prevent stream pollution.

Operation is completely automatic! The float moves with the level of liquid in waste tanks . . . keeps the lip of the skimming trough the desired fraction of an inch below the surface at all times. Floating oil flows over the trough-lip and is sucked up through hose to reclaiming tank.

WRITE FOR FREE BROCHURE!

Simplex Valve & Meter Company, 6719 Upland St., Philadelphia 42, Pa.

SIMPLEX®

VALVE AND METER COMPANY

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Montana Sewage and Industrial Wastes Assn.	Hotel Baxter, Bozeman, Mont.	April 22, 1954
New England Sewage and Industrial Wastes Assn.	Hotel Somerset, Boston, Mass.	April 22–23, 1954
Arizona Sewage and Water Works Assn.	Santa Rita Hotel, Tucson, Ariz.	April 22–24, 1954
Maryland-Delaware Water and Sewage Assn.	Hotel Francis Scott Key, Frederick, Md.	April 29–30, 1954
California Sewage and Industrial Assn.	Hotel Senator, Sacramento, Calif.	May 5–8, 1954
Virginia Industrial Wastes and Sewage Works Assn.	Hotel Stonewall Jackson, Staunton, Va.	May 20–21, 1954
Michigan Sewage and Industrial Wastes Assn.	Kellogg Center, Michigan State College, East Lansing, Mich.	May 22–24, 1954
Alabama Water and Sewage Assn.	Pitts Hotel and Alumni Dorm, Auburn, Ala.	June 7–9, 1954
New York Sewage and Industrial Wastes Assn.	Hotel Syracuse, Syracuse, N. Y.	June 14–15, 1954
Institute of Sewage Purification	Jubilee Theatre, Coronation Street, Blackpool, Eng.	June 22–25, 1954
Central States Sewage and Industrial Wastes Assn.	Hotel Leland, Richmond, Ind.	June 24–26, 1954
Pennsylvania Sewage and Industrial Wastes Assn.	The Pennsylvania State College, State College, Pa.	Aug. 25–27, 1954
Iowa Sewage Works Assn.	Hotel Russell-Lampson, Waterloo, Iowa	Sept. 14–16, 1954
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Jackson Hotel, Nashville, Tenn.	Sept. 20–22, 1954
North Dakota Water and Sewage Works Conf.	Hotel Dakota, Grand Forks, N. D.	Sept. 22–24, 1954
Georgia Water and Sewage Assn.	Georgia Institute of Technology, Atlanta, Ga.	Sept. 22–24, 1954
New England Sewage and Industrial Wastes Assn.	Hotel Stratfield, Bridgeport, Conn.	Oct. 28, 1954

TWENTY-SEVENTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Ohio Sewage and Industrial Wastes Treatment Conference
Netherland Plaza Hotel, Cincinnati, Ohio
October 11–14, 1954

Briefs from the YEOMANS GUARD

Across the board— WIN, PLACE, and SHOW: the Treatment Plant at Tupelo

Take an appreciative look at these figures:

Daily flow	0.999 MGD
Raw sewage B.O.D.	286 ppm
Raw sewage, suspended solids	216 ppm
Final effluent B.O.D.	31 ppm
Final effluent, suspended solids	34 ppm
Overall reduction B.O.D.	89%
Overall reduction, suspended solids	84%

These are average figures, reported from August '52 to January '53, inclusive, of operating results at the treatment plant in Tupelo, Mississippi.

It's a Yeomans plant—consists of a primary Spiraflo Clarifier, an Aero Filter Distributor and final Spiraflo Clarifier; plus a full quota of necessary pumps. It handles industrial wastes and domestic.

Simplicity of operation was a prime requisite; and the plant operates automatically with electrical control.

Further, its high efficiency is matched by its exceptional economy.

Still more, it's a sightly plant—bespeaks an alert, heads-up well managed community.

A full report covering plant details and performance data on request.

☐ Please send Tupelo report.

easy
- *to select*
- *to install*
- *to pay for*

this NEW PACKAGE SEWAGE LIFT STATION

A practical answer to an urgent and growing need for a low-priced, easily installed "package" dry pit sewage lift station for small residential units: our new "Package" Sewage Ejector Series 6280.

No Selection Problem—A simple matter to choose the right model by *population to be served* and the discharge head.

No Installation Problem—It's a "package"—complete, ready to place in the pit and connect.

No Payment Problem—simple in design, standardized, this compact unit is low priced, easy to pay for.

See Bulletin 6251, page 8.

☐ Please send Bulletin 6251.

Difficult Industrial Wastes Successfully Treated in Yeomans Plants

A number of industrial wastes, including some described as "difficult," are being treated in Yeomans plants—with results described in some instances as "miraculous."

Efficient treatment is the main objective, of course; but the extraordinarily low cost of Yeomans plants—as to both construction and operation—is a factor that is pleasant to consider.

If you have a knotty problem of industrial waste treatment, it makes much sense at absolutely no cost to find out how we may be able to help solve it. Just write a letter.

The Yeomans Guard, published several times a year, is a compendium of news and useful information covering the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue if you'd care to have it. Ask your local Yeomans Representative—listed in the telephone book yellow pages under "Pumps"—or write direct.

YEOMANS BROTHERS COMPANY

1999-7 N. RUBY STREET, MELROSE PARK, ILLINOIS

Manufacturers of: Centrifugal Pumps and Pneumatic Ejectors for Buildings, Municipalities, and Industrial Applications, and a Full Line of Waste Treatment Equipment.

With 100 years

Ewing Galloway

This is New York, as seen from East River, showing Empire State, Chrysler and United Nations buildings.

Bettmann Archive

Old print showing cast iron water mains being installed in New York about 100 years ago.

MODERNIZED **cast iron**

# of EXPERIENCE... they must be right!

NEW YORK installed cast iron water mains 100 years ago... and installs them today!

One hundred years ago, New York was a city of about 750,000 population, served by 237 miles of water mains. Today's eight million population requires 5500 miles of mains, of which 98% are cast iron. Some of these mains are still functioning after a century and more of service. From 90 M.G.D. a century ago, capacity has grown to 1500 M.G.D.

A customer who buys your product year after year—generation after generation—is a "jewel beyond price". Be you merchant or manufacturer, you might count such customers on the fingers of your two hands. Yet, the cast iron pressure pipe industry can count more than 60 of them—utilities that have been buying cast iron pipe for water or gas mains (or both) for 100 years.

Cast iron pipe has been a rugged, long-lived product from the earliest days. Today's *modernized* cast iron pipe, centrifugally cast, is even stronger, tougher, and more uniform in quality. And, where needed and specified, it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout the long life of the pipe.

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3.

In good condition after 100 years of service, this cast iron distribution main is one of several still functioning in New York City.

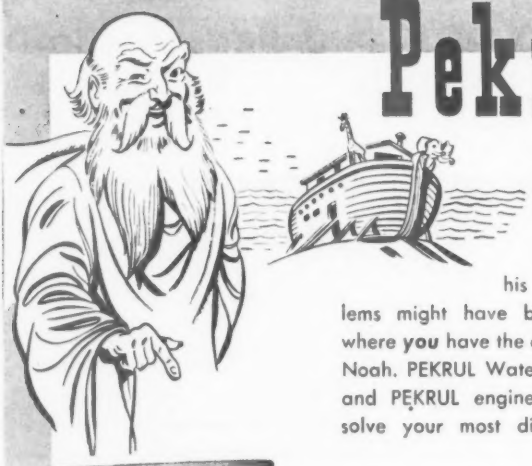
CAST IRON

The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS OPERATION

If Noah had known about...

Pekrul Gates



his water control problems might have been easier. There's where **you** have the advantage over poor Noah. PEKRUL Water Control Equipment and PEKRUL engineers stand ready to solve your most difficult requirements.

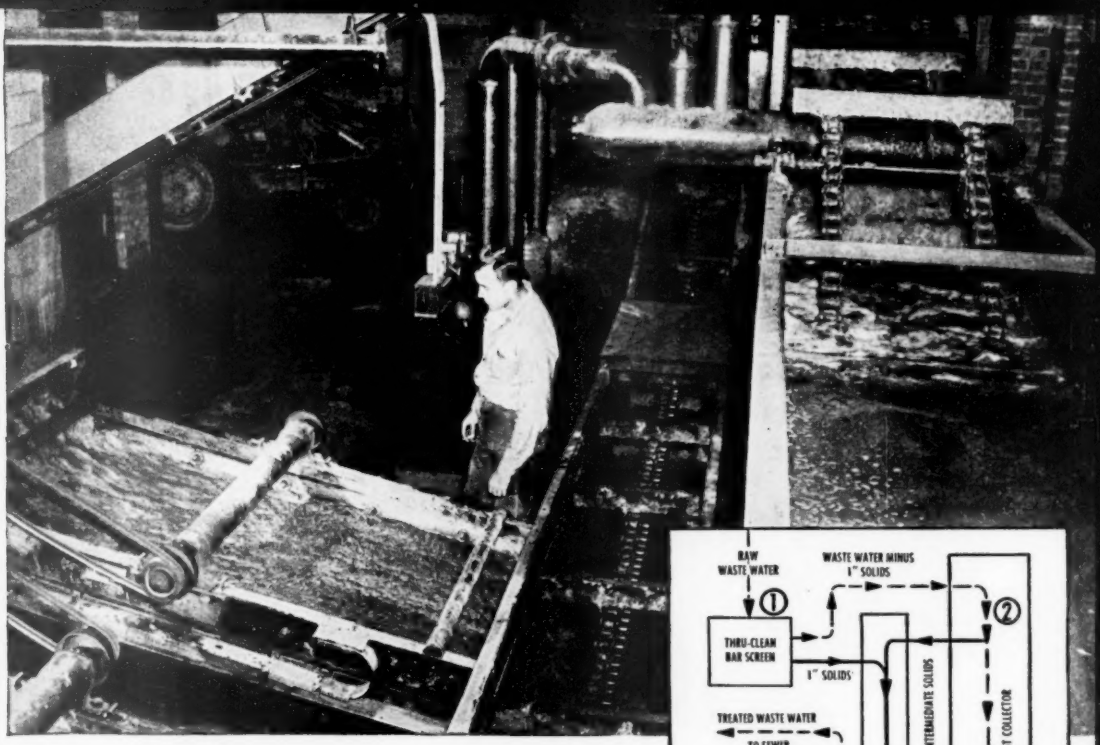
Manufacturers of Pekrul Gates for

FLOOD CONTROL
LEVEES
IRRIGATION
WATER WORKS
DAMS
SEWAGE DISPOSAL
RESERVOIRS
PUMPING PLANTS
OIL REFINERIES
FISH HATCHERIES
REARING PONDS
RECREATION POOLS
COOLING TOWERS
STEEL MILLS

PEKRUL GATE DIVISION

Write for Catalog 49

MORSE BROS. MACHINERY
DENVER, COLORADO



Lakeside's waste water passes through a Link-Belt Thru-Clean Bar Screen (1), where over-1-in. solids are removed and chuted to the Link-Belt Flight Conveyor. The effluent next goes to the Straightline Grit Collector (2). Here grit and canning wastes that settle out are discharged to the flight conveyor. The water then flows over two Link-Belt Liquid Vibrating Screens (3), where the last of the objectionable solids are separated and the waste water is piped to the sewerage system.

Here's how one plant cleans up its waste water

Compact, efficient LINK-BELT treatment equipment installed at Wisconsin cannery

LIKE many other plants, Lakeside Packing Co. of Manitowoc, Wis., had a problem of how to remove waste from its wash water before discharging it into the municipal sewerage system. And, just as many others have done, they called in Link-Belt engineers.

The efficient Link-Belt system now employed removes solids from the water in three stages at a peak rate of 24,000 pounds a year. This waste is trucked away to be used as fertilizer and feed.

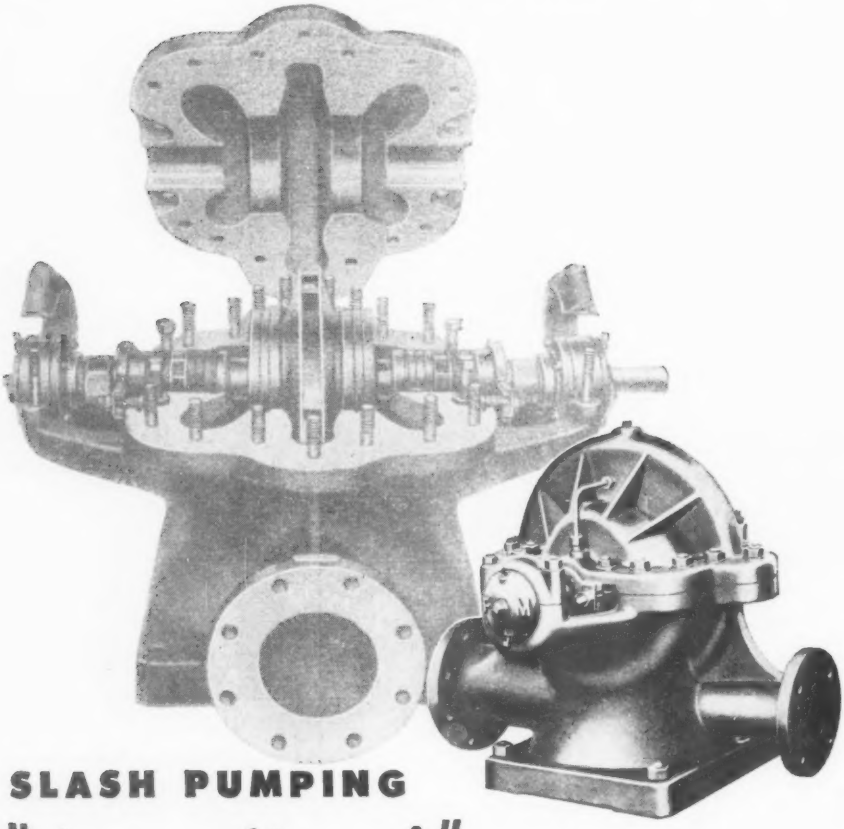
There are other benefits of a Link-Belt waste treatment system. Your waste water may be carrying valuable material down the drain or clogging your sewers. No matter what your problem, Link-Belt experience and equipment assure the system best suited to your needs. Call the Link-Belt office near you for complete information.

13,482

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT



SLASH PUMPING

"down time!"

You slash pumping "down time"—when you have a pump that requires minimum maintenance . . . when the parts are easily accessible when maintenance is necessary . . . when you have a Fairbanks-Morse Split-Case Centrifugal Pump!

See how easily this sturdy pump is inspected . . . lift the split casing and the entire rotating element can be removed without disturbing driver or pipe connections . . . even the bearings can be removed without use of a bearing puller!

See your Fairbanks-Morse Branch Pump Engineer on this Split-Case Single-Stage Centrifugal and the rest of his complete pump line. Fairbanks, Morse & Co., Chicago 5, Illinois.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES & ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS

TEFLON GASKETS

make a difference in performance!

By equipping every a.c.f. Lubricated Plug Valve with the new Teflon Gasket, we have lengthened service life while improving operation.

You get greater protection against head leakage... trouble-free operation in temperatures up to 450° F. Greatly reduced turning torque.

What's more, this new gasket—tested in the field for four years under the most exacting conditions—is a discovery that can mean substantial savings in time and money. Investigate today! See your a.c.f. Representative for the complete facts.

Gasket characteristics:

self lubricating • can't bind • unique shape maintains lubricant release • pressure tight

Round Port Valves — 100% Obstruction Free
Rectangular Port Valves with Full Pipe Area
Venturi Valves for Economy

a.c.f. CYLINDRICAL FULL PIPE AREA **PLUG VALVES**

Representatives in 50 Principal Cities

Write for Catalog No. 4-SE and Price List
American Car and Foundry Company,
Valve Division, 1501 E. Ferry Ave., Detroit 11, Mich.

HERE'S YOUR SOLUTION

Every grit problem is *different.* Velocities, head loss, hydraulic characteristics of chambers, capacities, grit size and type, and site conditions—all these factors must be considered in designing efficient grit chambers and collector equipment. There is no one standard design that can be applied to all problems. That's why Chain Belt studies each application carefully, and from our 17 years of experience, we recommend the chamber and equipment you need for most efficient results. In the complete range of Rex® Grit Collectors, there is a basic type that can be best adapted to your individual needs.

Take Advantage of These Rex Advantages

Rugged Design...to withstand the corrosive and abrasive conditions... heaviest loads.

Flexibility of Application... grit channels designed for each application ...widest selection of types and equipment.

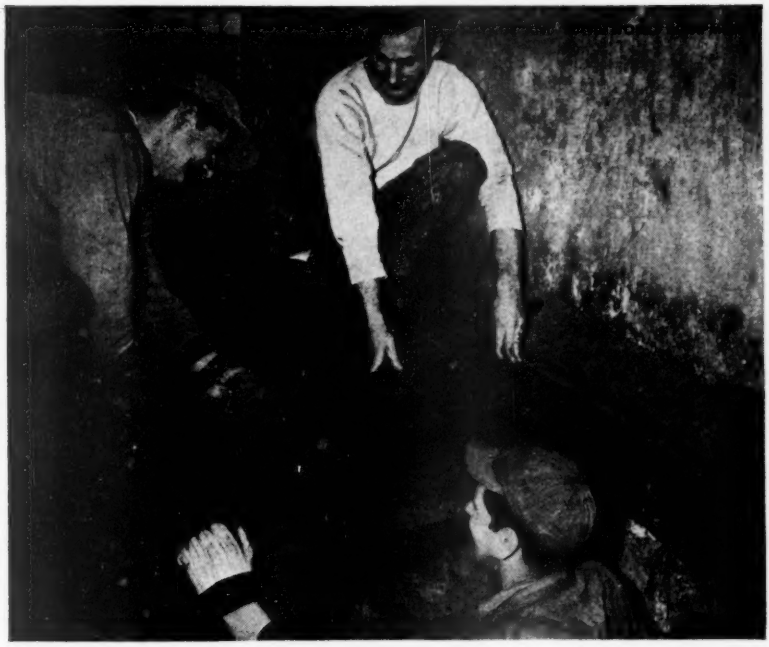
Effective Grit Recirculation... material with excessive organics or improperly separated materials can be recirculated through the channel for resettling.

Neat Appearance...head shaft housing completely enclosed. Factory sub-assemblies...cut costs and increase equipment life.

For complete information, see your nearest Rex Sanitation Engineer or write Chain Belt Company, 4610 W. Greenfield Ave., Milwaukee 1, Wis.

CHAIN BELT COMPANY

District Sales Offices in all principal cities



SCREENS:

EASILY FABRICATED OF EVERDUR FOR EXTRA CORROSION RESISTANCE

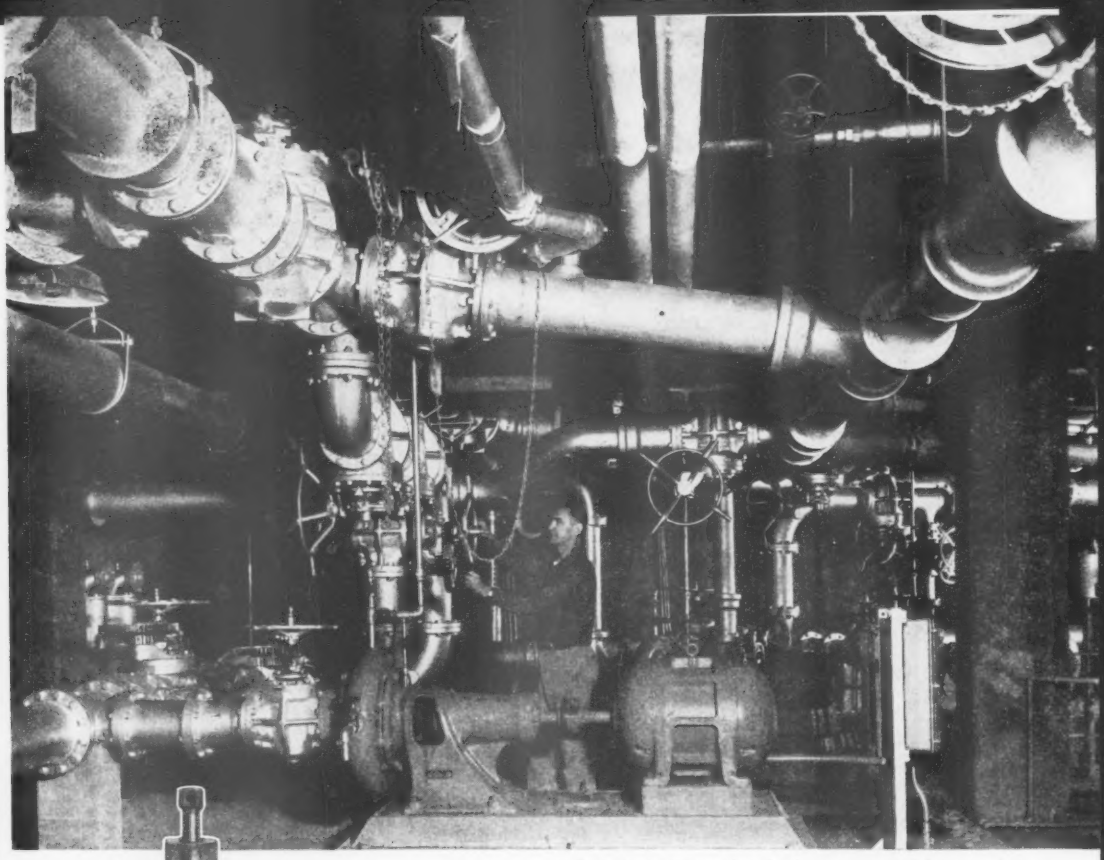
Fabricated of Everdur* Copper-Silicon Alloys, this sewage screen offers years of protection against corrosion at all stages of sewage treatment. Everdur alloys are the standard for equipment where high corrosion resistance must be incorporated into readily fabricated, lightweight structures.

Everdur applications include gates, guides and bolts, valve and gate stems, weirs, float chambers, troughs, manhole steps and electrical conduit. These highly corrosion-resistant alloys are characterized by great strength and excellent working properties. Depending on which alloy is used, Everdur may be worked hot or cold, welded, machined, forged or cast and is available in plates, sheets, rods, tubes, electrical conduit and casting ingots.

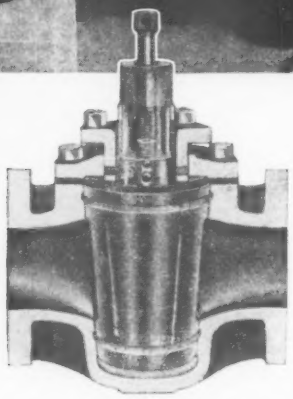
If you would like detailed information for specific applications or designs, the services of our Technical Department are always available to you. Our Publication E-11 describes Everdur Alloys and applications in detail. Write for it. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

*Reg. U. S. Pat. Off. 53138A

EVERDUR
ANACONDA®
COPPER-SILICON ALLOYS
STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT



Does this look like a lot of valves on one unit? See copy below.



Cutaway view of a Rockwell-Nordstrom valve showing the grooves which carry lubricant to all areas of the seating surface.

ROCKWELL-
Nordstrom
VALVES

Lubricant-Sealed for Positive Shut-Off

ANOTHER PRODUCT

The Answer to Sewage Valve Problems . . . STANDARDIZE ON ROCKWELL-NORDSTROMS

This photograph shows Rockwell-Nordstrom gear-operated valves on digester feed lines to the sludge withdrawal pumps in a Midwest sewage treatment plant. There are approximately 100 such valves on this unit alone. But whether they are installed on sludge lines, water lines or sewage gas lines, Rockwell-Nordstrom valves out-perform and outlast any other type.

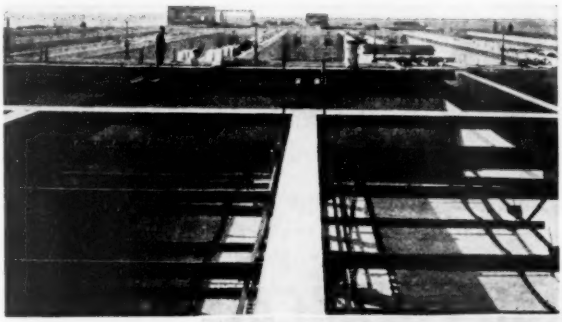
Rockwell-Nordstrom valves are built on an entirely different principle than most valves. Instead of a metal-to-metal closure, a film of pressurized lubricant surrounds the seat ports preventing flow of the line fluid around the plug. This lubricant keeps the valve ready to operate easily with a quick quarter turn, too. In addition, the vital seating area is protected from corrosion because *it is never exposed to the line fluid.*

End your sewage valve problems by standardizing on the best valves for sewage treatment services—Rockwell-Nordstrom lubricant-sealed valves. Rockwell Manufacturing Company, Pittsburgh 8, Pa. Canadian Licensee: Peacock Brothers, Limited.

Engineer Bogert Childs *specifies*

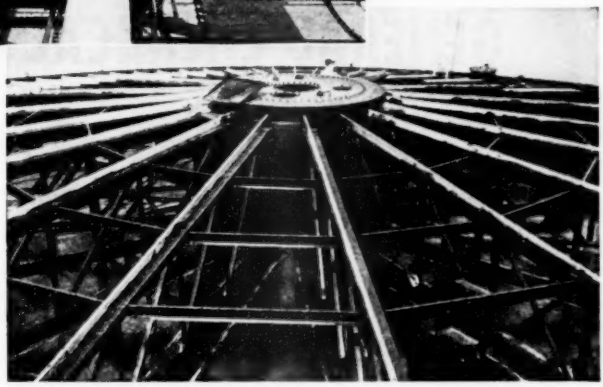
INERTOL PAINTS

for Overpeck Valley Sewage Project



A-1 protection for submerged concrete and metal surfaces was achieved by using Inertol Standard and Standard Thick. Both coatings help accelerate flow of sewage . . . clean *easily*, too!

Structural steel got coatings of Inertol Black Bituminous Paints. Sparkling and long-wearing Inertol colored enamels were specified for floors, walls, ceilings, machinery and railings. They retain their beautiful high gloss . . . are mar-resistant!



REASON: ***They're made especially for sewage plant use!***

Plenty of thought and research went into the paint choice of Bogert Childs Engineering Associates of New York City in selecting protective coatings for the Overpeck Sewage Project (Bergen County Sewer Authority, Overpeck Valley Joint Sewer Commission, Little Ferry, N. J.). They demanded coatings that would assure a maximum of inertness, elasticity, hardness and water-resistance. They found that Inertol Paints *more* than meet those strict requirements.

The famous long-lasting quality of Inertol Paints – *plus* long-run economy – has been proved by use in thousands of installations from coast to coast. And Inertol coatings will prove themselves for you, too. Get the full story on Inertol's many durable attractive coatings by asking to have an Inertol Field Technician call on you. There's lots of good information in our free pamphlet "Painting Guide," too. If you're a Specification Writer, Design Engineer, Contractor or Plant Superintendent, you'll want a copy right away – so write *today!* It's *free!*

INERTOL CO., INC.

482 Frelinghuysen Avenue
Newark 5, New Jersey

27H South Park
San Francisco 7, California

for water:
To remove turbidity, color and other impurities

for sewage:
For clarification . . . to floc out suspended colloids and solids—
For sludge . . . to speed drying

GENERAL CHEMICAL "ALUM" is preferred

Here's why water experts and sewage experts alike agree on General Chemical Aluminum Sulfate.

For over 50 years, General Chemical "Alum" has had a reputation for meeting the most rigid chemical and physical specifications of the water and sewage industry. In scores of cities throughout America, public works officials depend on its uniformity and quality.

And, they also depend upon General's coast-to-coast producing and distributing facilities to meet their day-to-day and emergency needs. General has an "alum" supply point near you, too. So, for your operations, specify the *preferred* aluminum sulfate—General Chemical "Alum."

GC Allied Chemical

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston
Bridgeport • Buffalo • Charlotte • Chicago • Cleveland • Denver
Detroit • Greenville (Miss.) • Houston • Jacksonville • Kalamazoo
Los Angeles • Minneapolis • New York • Philadelphia • Pittsburgh
Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)
In Wisconsin: General Chemical Company, Inc., Milwaukee
In Canada: The Nichols Chemical Company, Ltd. • Montreal • Toronto • Vancouver

A Better America Through Chemical Progress • CHEMICAL PROGRESS WEEK • May 17 to 22, 1954

Two Bests

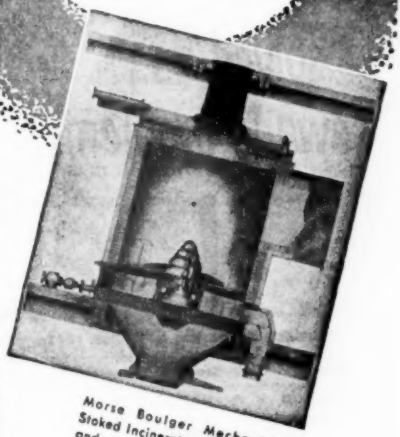
1
WASTE DISPOSAL BY INCINERATION

2
INCINERATORS BY SPECIALISTS

Select from this list of five different types and you will get the best type for your particular problem whether it is trash, garbage, sewage sludge, institutional organic matter . . . separately or in combination.

- **For Garbage and Rubbish**
  - **(1) Cell and Hearth**
  - **(2) Circular Hearth and Grates — Mechanically Stoked**
- **For Sewage Sludge Drying and/or Burning**
  - **(3) Multiple Zone Furnace—Mechanically Stoked**
- **For Garbage, Rubbish and Sewage Sludge**
  - **(4) Circular Unit, Mechanically Stoked, with Separate Compartment for Sewage Sludge Reduction**
- **For Garbage and Trash (Individual Buildings)**
  - **(5) Kernerators (Flue-Fed and Ready-Built)**

Our incinerator experience goes back nearly sixty years. Our work is guaranteed. Our incinerators are constructed under the supervision of our own field men who stay with it until the unit is in operation, fully broken in and crews instructed.

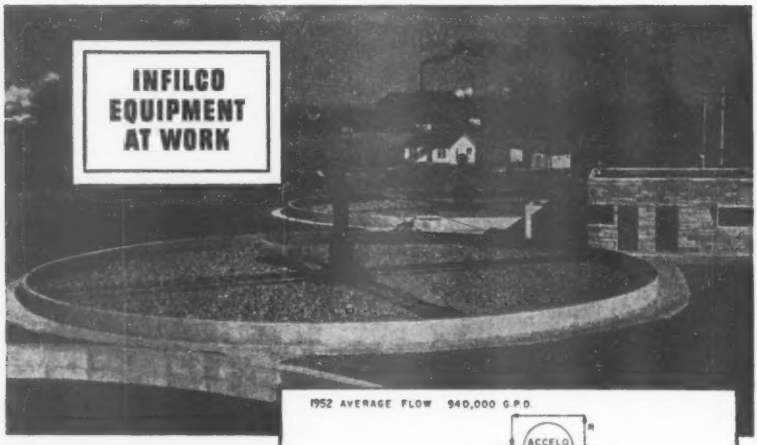


Morse Boulger Mechanically Stoked Incinerator, circular hearth and grate, for garbage, rubbish and all kinds of industrial wastes.

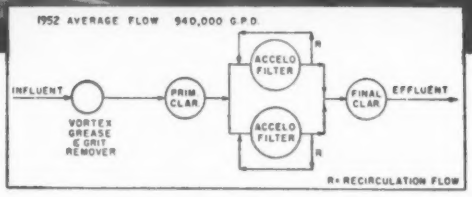
MORSE BOULGER DESTRUCTOR CO.

205-S East 42nd St. **New York 17, N. Y.**

Representatives in Principal Cities



1952 AVERAGE FLOW 940,000 G.P.D.



Here's how WASHINGTON, IND.

solved its sewage problems...

Like many other small-but-growing communities, Washington, Indiana, required sewage treatment facilities able to do a complete job at low cost.

Working with J. B. Wilson, Consulting Engineer, Indianapolis, they achieved this effective, economical operation. The Vortex Grease and Grit Remover and PD Clarifier effect a 72% BOD reduction. Low-cost secondary treatment is accomplished through direct recirculation around Accelo® Filters.

AVERAGE OPERATING DATA FOR 1952:

Analysis	Raw Sewage	Primary Effluent	Plant Effluent
5-Day BOD	129	36	21
Suspended Solids	114	29	21

Infilco equipment and processes can solve your sewage problems...

Send this coupon for more information

INFILCO

INFILCO INC. *Tucson, Arizona*

Plants in Chicago and Joliet, Illinois

FIELD OFFICES IN 28 PRINCIPAL CITIES

INFILCO INC., P. O. Box 5033, Tucson, Arizona

Please send me a copy of Infilco Bulletin 6200-S.

NAME_____

TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

Count costs in pennies

Thirty cents per dry ton of sewage sludge incinerated. That is the average annual maintenance cost of a typical Nichols Herreshoff dryer-incinerator over years of continued, dependable service.

Only the Nichols Herreshoff multiple hearth furnace combines proved low operating cost and rugged construction with dual-purpose adaptability to burn all types of sludge to a sterile ash or dry it to a product excellent for soil conditioning.

The Nichols Herreshoff sludge dryer-incinerator is a development of Nichols world-wide multiple hearth experience in the chemical, metallurgical, cement and process industries. Thousands of these furnaces are now in operation.

Nichols Herreshoff

Multiple Hearth Dryer-Incinerators

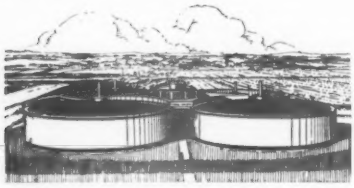
Nichols Engineering and Research Corp.

70 Pine St., New York 5, N. Y.

1637 N. Illinois St., Indianapolis 2, Ind.
40 S. Los Robles Ave., Pasadena 1, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

New developments in "controlled digestion"

A STATEMENT OF POLICY



In the development of controls for the separate sludge digestion process, the Pacific Flush Tank Company has been a leading contributor. The P.F.T. Floating Cover was developed to provide means for positive submergence of the scum in the seeding liquor and allow safe gas utilization. P.F.T.'s development of external heating of recirculated digester contents and raw sludge assures the maintenance of constant optimum digester temperatures. And more recently the development of the P.F.T.-Pearth Gas Recirculation System provides a positive means for the rapid dispersion and elimination of scum accumulations.

Our Policy is Clear — With our many contributions to the basic knowledge of the sludge digestion process, it has always been our policy to point out the advantages of closely controlling all factors affecting digestion. With effective controls, operational difficulties are eliminated and successful digestion results—the production of an inoffensive sludge of uniform concentration suitable for ultimate disposal.

We will continue to advocate the use of established design criteria for digestion capacity as formulated by consulting engineers and State Boards of Health. We feel that these criteria are developed to take into consideration practical plant operating procedures and future requirements. These criteria cannot be based solely upon results of pilot plant studies which require careful control by staffs of highly skilled technicians.

The introduction of the P.F.T.-Pearth Gas Recirculating System provides an economical means of dispersing scum accumulations, making the total digester volume available for effective digestion. There is no *mysterious* action in the operation of any gas recirculating system. It is merely a *mechanical* action which aids the normal biological activity by breaking up the scum so that it can be digested.

To those interested in sewage and waste treatment, Pacific Flush Tank Company will continue to offer straightforward information about all of its equipment and new developments.

P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

4241 Ravenswood Avenue
Chicago 13, Illinois

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • JACKSONVILLE • DENVER

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **April, 1954** **Number 4**

Contents

Sewage Works

Scum Control in Sludge Digestion. By Ralph E. Fuhrman 453
Discussion by L. E. Langdon 458
Studies of Accelerated Digestion of Sewage Sludge. By Philip F. Morgan 462
Discussion by James H. Blodgett 476
High-Rate Digestion of Concentrated Primary and Activated Sludge. By Wilbur N. Torpey 479
Discussion by R. S. Rankin 494
Radium as a Tracer in Sewage Flow Measurements. By T. G. Bullen and W. F. O'Connor 497
Research on Activated Sludge—A Discussion. By Henry R. King 508

Industrial Wastes

Clarification by Flotation and Re-Use of Laundry Waste Water. By Herbert J. Wollner, Victor M. Kumin and Peter A. Kahn 509
Deep-Water Disposal of Pulp Mill Wastes into Port Gardner Bay, Everett, Washington. By Gerald T. Orlob and E. F. Eldridge 520
Gravity Separation of Silt from Industrial Wastes. By C. L. Siebert, Jr. 531
Toxicity of Mercuric Chloride, Chromic Sulfate, and Sodium Chromate in the Dilution B.O.D. Test. By a Subcommittee on Toxicity of Industrial Wastes 536

Stream Pollution

Fungi in Polluted Water and Sewage. I. Literature Review. By Wm. Bridge Cooke 539

The Operator's Corner

Record and Reporting Policy in New York City Sewage Treatment Plants:
I. Operation Records. By F. H. A. Lino 550
II. Laboratory Records. By Robert Shapiro 558
III. Bureau Policy. By Arthur J. Scanlon 560
Helps to Plant Prestige and Public Relations. By George T. Lohmeyer 562
Interesting Extracts from Operation Reports: Detroit, Mich.; Aurora, Ill. 564
Simplified Method for Determination of Oil in Waste Waters. By Robert E. Beaudoin 568
Tips and Quips 569

Book Reviews 572

Proceedings of Member Associations

New England Sewage and Industrial Wastes Association 150a
Oklahoma Water, Sewage and Industrial Wastes Conference 152a

Equipment and Supply Lines 154a

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*
Mrs. A. H. Skates, *Editorial Assistant*

Copyright, 1954, by the Federation of Sewage and Industrial Wastes Associations. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

. . . take the Jamaica, Long Island Sewage Treatment Works for example —

In 1941, the New York City Department of Public Works installed eight 120′ dia. Dorr Clarifiers equipped with skimming arms for final sedimentation at the Jamaica Sewage Treatment Works. Overall plant design capacity is 60 MGD utilizing the modified aeration process.

Here's the cost record for repair parts after 11 years of operation:

Total repair parts cost	$3,707.38
Repair parts cost per unit/per year	42.13
Yearly repair parts cost as % of total equipment investment	0.57%

Repair costs are one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?

We'd like to tell you how Dorr Clarifiers stack up on performance too. Ask a Dorr Engineer for the facts.

It will pay you to send your CLARIFIER problems to DORR.

Better tools TODAY to meet tomorrow's demand

DORR

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.

Offices, Associated Companies or Representatives in principal cities of the world

Sewage Works

SCUM CONTROL IN SLUDGE DIGESTION *

By Ralph E. Fuhrman

Deputy Director, Department of Sanitary Engineering, District of Columbia, Washington, D. C.

For many years those concerned with the design, construction, and operation of facilities for the digestion of organic sludges have been faced with serious problems of scum control in digestion tanks. For the first quarter of the Twentieth Century, the battle was fought in the septic tank and the Imhoff tank. During the second quarter, the battle has been associated with separate sludge digestion tanks.

About 30 years ago, one of the country's eminent sanitary engineers, Harrison P. Eddy, Sr., urged that the biological and physical phases of sludge digestion be made the subject of research work to aid in the development of the art of sewage treatment. Since his charge, many others have expressed a need for some means of digester scum control. Through the years vast improvement has been made in the art because of the generally better control of the sludge digestion process. There has been developed the heated digestion tank, the floating cover, and the use of sludge gas for power production and many other purposes. At the same time there has taken place improvement after improvement, some short-lived, others long-lived, but all generally contributing to the practice as it is known today. There have been improvements in tank heating techniques, frequently combined with stirring or circulating devices, which, in general, have been accelerated from slow-speed to high-speed applications of one kind or another. A detailed review of all the physical and chemical methods that have been developed is not necessary here, as these are readily available in the literature.

Scum Problems

The objectives being sought continually are better control to achieve greater reliability and economy in operation and, of at least equal importance, the speeding up of the digestion process to a practical maximum in order to make the most efficient use of digester space. Eddy urged research on "the effect on permissible load, of continuous artificial agitation of scum to an extent which will cause the solids to remain in the sludge mass practically all the time." Evidently he had recognized the need for a method of scum dispersion by agitation.

Whatever beginning the method to be described here may have had may be traced in a large degree to the load imposed by the rapid and continuous population growth of the District of Columbia and the contiguous Maryland suburbs served by the District of Columbia sewage treatment plant. By the time the plant went into service in August, 1938, the design population of 650,000 was already contributory. With the wartime growth of the area in the 1940's, a severe population overload was imposed on the original eight sludge digestion tanks. The original design allowance of 1.75 cu. ft. per capita soon shrank to about 1.0 cu. ft.

* Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; October 13–16, 1953.

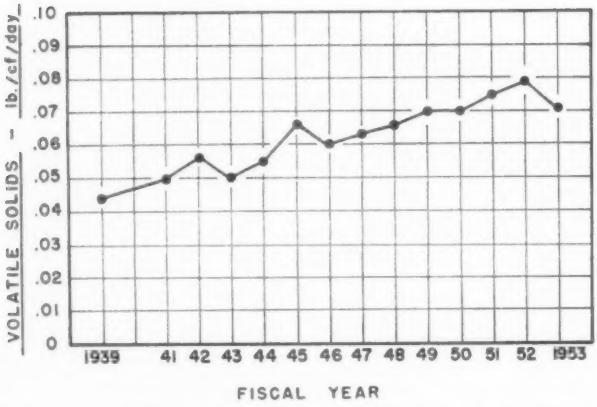


FIGURE 1.—Average volatile solids loading on digestion tanks at District of Columbia sewage treatment plant.

per capita. On a volatile solids loading basis, the over-all load increased from 0.04 to 0.08 lb. per cubic foot per day, based on total tank volume. The tanks, 84 ft. in diameter, have fixed covers and no stirring mechanism of any kind. They receive sludge and scum from primary settling tanks. Figure 1 shows the average load on the tanks since initial operation.

Early in the operation of these tanks it became apparent that a heavy scum blanket in the tanks was limiting their effectiveness. In other words, it appeared that the load on the tanks could be increased but for the problems created by excessive scum depths. The scum, resulting from domestic sewage, is perhaps as near normal in composition as might be encountered, as there are practically no industries in the area served. In addition to the loss of digestion space to scum, it was also found that the accumulation of coarse sand which has passed the grit chambers had built up on the tank bottoms to 10 or 15 per cent of the total tank volume. The combined effect of loss of space to scum and sand reduced the effective tank volume by at least one-third and consequently increased the unit loading by 50 per cent on the basis of useful tank volume.

The problem of coping with scum volumes up to 10 acre-ft. presented an unusually challenging problem to the operating staff. As it was impossible to remove the material by pipeline connections to the tanks, it appeared that dissipation of the scum would have to be accomplished somehow. It would be pointless to describe all of the methods attempted to break up the scum. It is sufficient to state that practically all physical methods known were tried. Some seemed effective at the outset, then later proved to be disappointments. Some seemed worthless from the first trial.

Development of Method

Finally, after trials first applied in the laboratory, a method was developed that stood every test of time and application that could be devised. The method consists essentially of injecting sludge gas into the digester below the scum layer at a rate that brings about the disintegration of the scum. When applied to a new tank, the formation of a dense scum cap is prevented. When applied to a tank with a heavy scum cap, the effect is to disperse the scum cap, and then to prevent its formation again. As power requirements of the method are low, the

method may be operated at a reasonable cost.

For want of a better name, the term "Pearth" was formed from the initials of six members of the operating staff of the District of Columbia sewage treatment plant who were active in the development of the method. The name has been retained by the Pacific Flush Tank Company, which controls the patent granted on the process. The method has seen regular service in the digesters of the District of Columbia plant for several years. It has been demonstrated at other plants, and has recently been installed in a new floating cover digester at the Coal Creek Plant of Tulsa, Okla.

To the observer, the dispersion of scum by this method is almost unbelievable. In the first trials at the D. C. plant, application was made to a tank with a very heavy cap, about 8 to 10 ft. in depth. For a short time after the gas discharge was commenced, nothing was apparent in the tank. Within a minute or two a boil formed and broke a hole in the scum. This was followed by a rising stream of supernatant liquor induced by the upward surge of gas. Even with the dense cap, a hole 5 ft. in diameter was made in 5 min. or less. As the action continued, chunks of scum broke off, toppled into the pool of agitated liquor and disintegrated from the violent circulating action. By applying the discharge at two additional points the cap was ruptured to the point of complete discontinuity. The islands of scum so formed traveled around the tank surface until their erosion was complete.

Before the regular adoption of the Pearth method of scum control at the D. C. plant, it was an all-too-frequent sight to have scum discharges through the relief manholes in the tank tops. When this occurred, a large amount of sludge gas was lost, as the whole gas system would flow to atmosphere until checked. An additional loss was the extra labor to remove the scum, at a cost of about $100, and the destruction of the lawn, as well as the unsightliness and odor nuisance of the discharge. After regular use of the system on a rotation basis of one compressor for eight tanks, no scum loss occurred because of clogging of pipelines by scum.

An attempt has been made to show quantitatively the effects of scum dispersal on a tank. The visual effects created by the gas circulation are so striking to the observer that he acquires a feeling of accomplishment even in the absence of analytical data. Never-

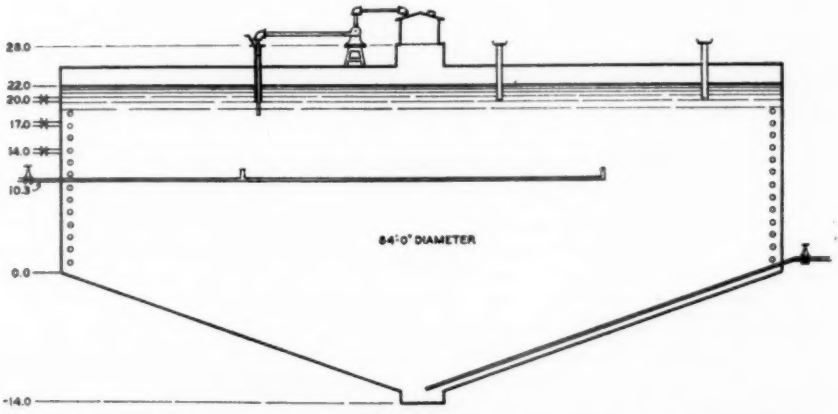


FIGURE 2.—Cross-section of digester set-up for scum destruction by gas recirculation.

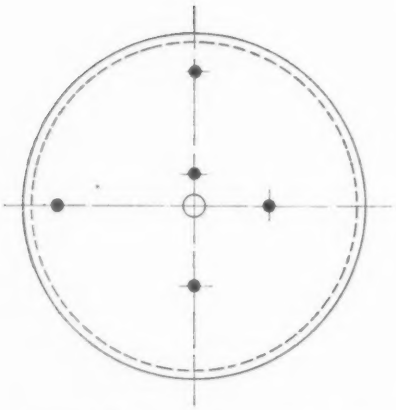


FIGURE 3.—Plan of sampling wells, digester No. 10.

theless, during August and September, 1953, controlled trials were made at the D. C. plant with measurements including scum depth and consistency, tank loading, analysis of tank contents throughout the tank depth, and gas production, in an attempt to indicate the effect of the process.

Trial Run

One of the four new digestion tanks placed in service about May, 1952, was selected for the trial. This tank had not had gas circulated in it previously. Figure 2 shows a general cross-section of the tank. The new tanks have five possible points of gas application originally installed for sampling wells, instead of three as in the original tanks, although only four were used in this trial. The location of the sampling wells is shown in Figure 3. The fifth well, near the center of the tank, was used solely as an observation and sampling well. Prior to this test run, as given in Table I, the tanks had been operating at an approximate average load of 0.049 lb. of volatile solids per cubic foot per day. During the 13-day period of August 20 to September 2, 1953, the tank operated without gas recirculation and with a volatile solids load of 0.064 lb. per cubic foot per day. The scum cap increased in depth from 7.5 ft. to 9.5 ft. At the latter depth, it occupied 35 per cent of the usable liquid volume of the digester. From September 3 through September 15, 1953, gas circulation at the rate of 140 c.f.m. was used for a total of 275 hr. or 88 per cent of the time. Before the circulation, gas was produced at the rate of 9.5 cu. ft. per pound of volatile solids added; during circulation the rate of gas production increased to 14.0 cu. ft. per pound of volatile solids added. There was no significant change in gas composition. Before circulation, the scum cap had 15.3 per cent total solids. Circulation during the test period reduced this to 12.4 per cent solids. The scum cap thickness was reduced from 9.5 ft. to 4 ft. in the 13-day period. The overall reduction of solids in the scum level during the 13-day circulation period amounted to 66 per cent. At this time, the rate of gas circulation was reduced to 40 c.f.m. for 14 days with the compressor running 79 per cent of the

TABLE I.—Operating Conditions and Results, Digester No. 10 [1]

Test Period	Date (1953)	Vol. Sol. Loading (lb./cu. ft./day)	Gas Production (cu. ft./lb. vol. sol.)	Gas Circulation		Scum Depth at End of Period (ft.)	Scum Solids at End of Period (%)	Total Vol. Solids at End of Period
				(% time)	(c.f.m.)			
1	through 8/19	0.049	5.7	0	0	7½	—	—
2	8/20–9/2	0.064	9.5	0	0	9½	15.3	50.9
3	9/3 –9/15	0.039	14.0	88	140	4	12.4	54.1
	9/16–9/29	0.047	10.5	79	40	—[2]	6.7[2]	62.6[2]

[1] Analytical results are on upper 8 ft. of tank contents.
[2] Pango sampler in central well revealed complete lack of dense scum cap.

TABLE II.—Results of pH and Alkalinity Determinations, Digester No. 10, during Test Runs

Tank Depth[1] (ft.)	pH			Alkalinity (p.p.m.)		
	Run 1[2]	Run 2[2]	Run 3[2]	Run 1[2]	Run 2[2]	Run 3[2]
+24	—[3]	—[3]	—[3]	—[3]	—[3]	—[3]
+20	—	—	7.6	—	—	4,600
+18	8.0	—	7.4	5,600	—	4,200
+17	—	7.6	—	—	4,850	—
+16	—	—	7.3	—	—	4,000
+14	—	—	7.3	—	—	3,800
+12	—	—	7.3	—	—	4,000
+11	7.3	—	—	3,300	—	—
+10	—	—	7.3	—	—	3,900
+ 8	—	—	7.3	—	—	4,100
+ 6	—	—	7.3	—	—	4,000
+ 5	—	7.3	—	—	3,200	—
+ 4	—	—	7.3	—	—	4,200
+ 2	—	—	7.3	—	—	4,100
+ 1	7.4	—	—	3,500	—	—
0	—	—	7.3	—	—	4,300
− 2	—	—	7.3	—	—	4,000
− 4	—	—	7.3	—	—	4,100
− 5	—	7.4	—	—	3,500	—
− 6	—	—	7.3	—	—	4,000
−14	—	7.3	7.4	—	3,500	4,200

[1] Above or below top of bottom cone.
[2] See Table I for dates.
[3] Maximum sidewall depth.

time. Dispersion of the scum continued, so that no cap as such could be measured. There was rather complete liquefaction at the tank top level with 6.7 per cent solids in the top 8 ft. Another effect was the increase in volatiles of this top material to 62.6 per cent. This is obviously the effect of indigestible floating material, such as wood chips, seeds, and hair, ordinarily present in the scum cap. In operating experiences at the D. C. plant, the appearance of such material in the sludge filter cake has been observed regularly when gas circulation has been employed. Removal of this material with the sludge from the tank bottom is the simplest and most economical method of removal.

Table II gives the pH and alkalinity determinations on the tank before and after gas circulation. It will be noted that the high values associated with the scum cap disappeared with the liquefaction of the scum.

Application of the method to sludge digestion tanks with floating covers appears to give similar results to fixed-cover tanks with a free top surface. The author has had the opportunity to witness the results of the method on the floating cover installed at the Tulsa, Okla., plant, as well as fixed-cover installations of Toronto, Canada, and two District of Columbia institutional plants. All of these applications have demonstrated the ability of gas circulation to disperse scum. Special observations have been made at the Tulsa plant to measure the effects on the tank there. As it was started without seed sludge, it is believed that alkaline digestion had not yet been established. In spite of this, the dense scum cap had been greatly thinned, even though there is an unusually large amount of hair contributed to this plant by packing houses. This hair has reached the lower levels of the tank. For this reason it will be re-

moved with the sludge with a minimum of trouble.

Conclusions

It is hoped that the method will provide operators with a useful method of combatting scum problems. Based on the experimental and long-term application of this work, the following conclusions are believed justified:

1. Employment of gas circulation will give positive and economical control of the scum normally present in sludge digestion tanks. In new tanks, formation of heavy scum will be prevented; in old tanks the scum will first be dispersed, then prevented from reforming by continued application of the method.

2. Application of the method will allow appreciable increases in digestion tank loadings. It is believed that loadings of at least 0.12 to 0.15 lb. of volatile solids per cubic foot per day could be applied to modern heated digestion tanks properly equipped with this method of scum control.

DISCUSSION

By L. E. Langdon

The success of Mr. Fuhrman and his associates in eliminating the scum from the digesters at the District of Columbia sewage treatment plant should be encouraging to the many sewage treatment plant operators who are faced with similar problems. That it has been possible to control the scum in the eight large unmechanized fixed-cover digesters with a single portable gas compressor is a tribute to their operating ingenuity.

In the description of the action taking place within the digestion tanks, it seems quite apparent that the disintegration of the scum layer is due principally to the mechanical agitating effect of the gas rising through the scum and carrying the underlying liquor through the scum mass. It is also quite apparent that by breaking up and inter-mixing the scum solids with the hot digester liquor carrying actively digesting solids, the organic matter will readily digest. This is merely the normal digestion which may be expected when favorable conditions of digestion are present.

That it is effective has not only been shown by the experience at Washington, but also at the other installations referred to by Mr. Fuhrman. It might be well to further discuss these installations.

At Toronto the digester installation is quite similar to that at Washington. The digesters have flat slab, fixed, concrete covers with no mechanical stirring, but are considerably larger, being 100 ft. in diameter and more than 30 ft. in depth. Because of the similarity of the two installations and the success at Washington, Mr. Fuhrman was invited to visit the Toronto plant early in 1952 to demonstrate how his method might be applied. In cooperation with the operating staff and consulting engineers, a temporary system was installed. This plant was at that time in the initial stages of digestion and provided no means for gas collection. The manholes and other openings in the cover were left open at all times. It was necessary, therefore, to use air as an agitating medium. The scum layer in the digester was very heavy and approximately 5 ft. thick.

Air was introduced at a depth of about 10 ft. below the liquid level in the tank at a rate of about 300 c.f.m. Operation was started at about 3 PM, and within 10 min. violent agitation and scum disintegration was evident at the surface of the tank adjacent to the

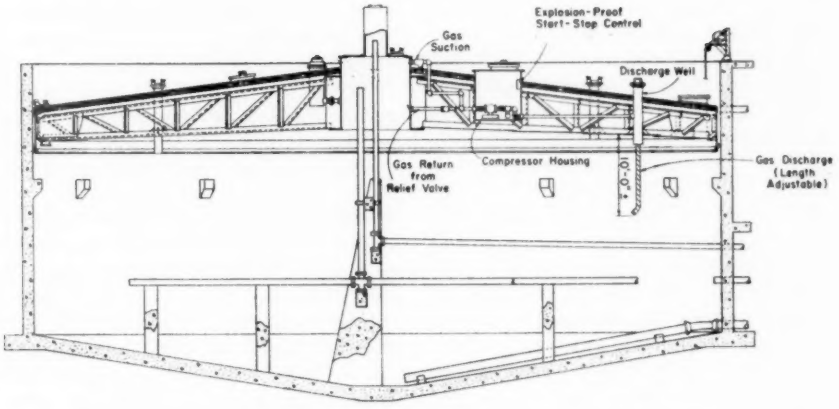


FIGURE 1.—Sectional view of Pearth gas recirculation on floating cover.

manhole. The point of application of air was changed successively to four open manholes in the top of the cover at 2-hr. intervals. By noon of the next day, after less than 24 hr. of operation, it was agreed that the demonstration was a complete success. The entire surface had been softened and was adequately fluid to pass through the overflow piping.

At present the City of Toronto is installing a permanent system of gas piping and an 80-c.f.m. gas compressor with suitable controls on one of the digestion tanks. The present scum layer is approximately 15 ft. in thickness and has an average solids content in excess of 20 per cent. An analysis indicates that about 60 per cent of the scum content is nondigestible materials. It is expected that with the gas recirculating system it will be possible to adequately disperse this scum

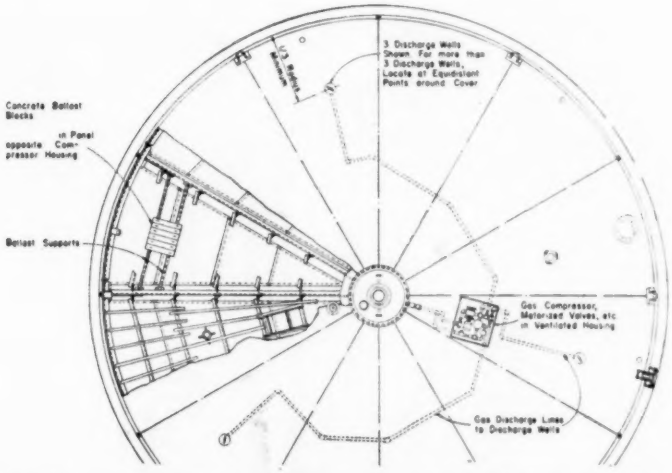


FIGURE 2.—Plan view of digester cover showing location of gas wells and other equipment.

so that it may be safely withdrawn through the overflow piping.

At the Coal Creek plant at Tulsa, Oklahoma, the first installation of the Pearth gas recirculation system on a floating cover has recently been completed. This plant has always had very heavy scum accumulations. The present installation of the floating cover replaces a fixed concrete cover that had been repeatedly ruptured due to the concentrated scum developed in this tank. A brief description of this installation will serve to explain the application of this gas recirculation system to a typical digester.

Figure 1 is a sectional view of the digester indicating the location of the explosion-proof compressor and controls in a fabricated steel housing built into the floating cover framework above the ceiling plate. A suction pipe is provided to withdraw the gas from the cover gas dome. Discharge piping from the compressor allows the gas to be discharged through any one of three discharge wells located equidistant around the floating cover. The location of these wells is shown in Figure 2.

The gas is discharged into the digester through an open-end pipe extending downward through the discharge wells to a point approximately 10 ft. below the ceiling plate of the floating cover. This depth may be varied, but should be just below the bottom of the expected scum layer and into the actively digesting liquor zone. In this manner the gas will be discharged from the open-end pipes in fairly large bubbles and will rise through the scum, carrying with it the hot, actively digesting liquor. By being discharged in large bubbles, a rather violent agitating action results at the surface of the cover; it is possible to feel the vibration on the cover as the gas comes to the surface.

By discharging just below the scum layer, only the upper portion of the digestion tank is disturbed. Those solids in the bottom of the tank which are

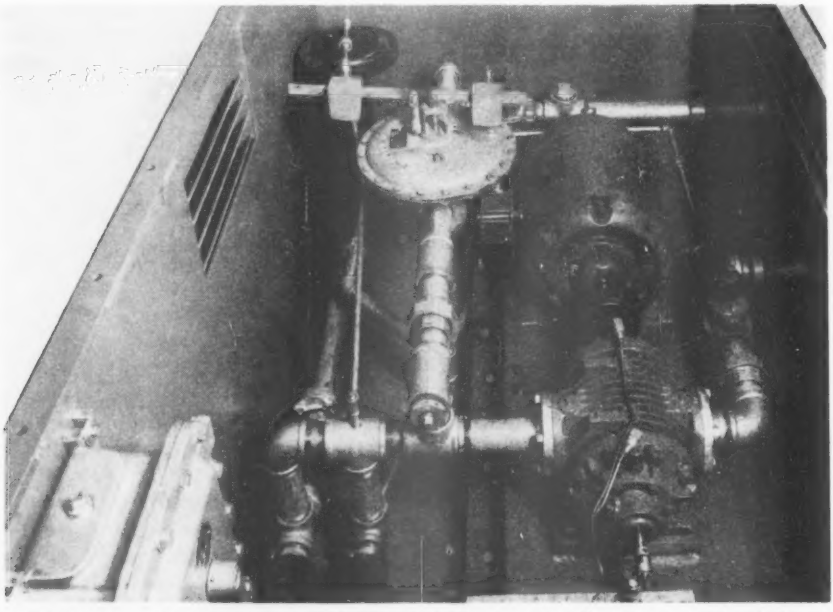


FIGURE 3.—Gas compressor and controls in housing for digester gas recirculation.

more completely digested are allowed to concentrate and be removed as digested sludge. Also, by discharging the gas at approximately the mid-depth of the tank, the operating pressure for the compressor is held to a minimum, resulting in the most economical operation.

In the interest of safety, in the operation of a gas recirculation system, the gas compressor within the structural steel housing and all electrical controls are explosion-proof. Figure 3 shows the equipment included in the compressor housing on the floating cover. The compressor for the 45-ft. diameter digester at Tulsa, Okla., has a capacity of 45 c.f.m. and is designed to operate against a pressure of up to 10 lb. per sq. in. In actual operation, the back pressure as observed is less than 5 lb. per sq. in. As the rate of gas production does not approach the capacity of the compressor, it is necessary that a control be provided to limit the amount of gas withdrawn from the gas dome at the time the compressor is started up. A by-pass regulator is provided on the discharge of the compressor to automatically by-pass from the discharge to the suction of the compressor during the start-up of operation until such time as the gas being recirculated builds up to equal the capacity of the compressor. This regulator is controlled to open the by-pass on a decrease in pressure in the gas dome, making it impossible to draw a vacuum on the gas dome of the cover.

The digester at Tulsa was put into service early in September, 1953. On September 20, a layer of heavy, sour, gray, greasy scum about 5 ft. deep, containing considerable quantities of hair was observed. The pH of the entire digester was approximately 5.0. A small amount of gas, principally CO_2, was being produced. The temperature of the digester was approximately 92° F. The gas recirculation system was started, although it was known that the digester was not in any condition for digestion. Within the first 24 hr. the scum at the center of the tank had been reduced by approximately 12 in. This continued to break up and be dissipated, until after approximately a week the scum was considered to be completely dispersed through the tank. The volatile acids in this digester, which was being heavily loaded, were reported in the range of 6,000 p.p.m. and no appreciable increase in digestion developed. The pH remained at approximately 5.0 during the entire period of operation. This would indicate that the entire dispersion of the scum in this tank was due to the mechanical agitation.

Mr. Fuhrman has indicated that with this gas recirculating system, as a new and effective tool for controlled digestion, increased digester loadings may be applied. It is not intended to recommend the upsetting of established standards, but it is thought that the elimination of the scum masses at the top of digesters will allow this additional space to be utilized to more effectively perform the complete functions of digestion, which are the destruction of the organic matter and the separation and production of a better and more concentrated sludge for disposal and further treatment.

STUDIES OF ACCELERATED DIGESTION OF SEWAGE SLUDGE*

By Philip F. Morgan

Professor of Sanitary Engineering, State University of Iowa, Iowa City, Iowa

The sludge digestion process utilized at municipal sewage treatment plants treats putrescible sewage solids so these solids can be economically disposed of by drying or burning without creating a nuisance. The changes which take place in the sewage solids during digestion are both biochemical and mechanical.

The biochemical changes resulting from the anaerobic bacterial process convert the sewage solids to stabilized reduced forms and to liquids and gases.

The mechanical action taking place is a simple separation of the wet compact sludge from the remainder of the liquid or supernatant.

These two phenomena may be carried on more or less simultaneously, as in a single-stage digestion tank, or can be separated, as in two-stage installations.

The relative capacity needed for each of the two phases, biochemical and mechanical, has never been well-defined and the over-all capacity commonly accepted for design purposes is such that the cost of digesters becomes a great part of the total cost of treatment plants. Further development to reduce the over-all cost of sludge digestion should logically be directed toward reducing the time required for each phase of the process, but particularly toward reducing the time required for the biological phase, since this is obviously the longest.

In 1946, Spiegel, Lamb, and Klein (11) undertook a study of the digestion process in an attempt to reduce the time required for the biological stabilization of the organic material. After considerable work, they developed, on a laboratory scale, a digestion process consisting of flash oxygenation of the raw sludge, addition of small quantities of carbon to the sludge in the form of finely ground coke, and recirculation of a proportional part of the digester gas, diffused into the sludge. The operating temperature was maintained at 95° F. The laboratory results showed that complete digestion, as indicated by a driable digested sludge and normal gas production per unit quantity of volatile solids added, could be completed within a 10-day displacement period, one-third of the 30-day period commonly used.

It was deduced that the operating procedure utilized, resulted in an environment favorable for intensified activity of the biological life responsible for the stabilization of the raw solids, thus making possible complete digestion in the 10-day period. The name "Catalytic Reduction Process" was adopted for this digestion method.*

The investigators, in cooperation with outside consultants, including a biological chemist, reviewed the progress of the work at this stage. They recognized the progress made, but could not explain the reasons for it. It was recommended that further work be carried on to find out more about the "how," without too

* Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953.

* This method and improvements subsequently developed are covered by patent applications filed by Chicago Pump Company, Chicago, Ill.

great concern about the "why." The future work, directed toward a study of the biochemical phase as distinct from the mechanical phase of the digestion process, was to be an over-all, comprehensive study, not a problem approach. The individual mechanical problems, of scum formation (1), sand deposition, heating (2)(3), supernatant separation (4), gas collection (5), safety protection (6), mechanical (7) and gas mixing (8), and pH control, had been studied by others in considerable detail for the conventional digestion process, so this approach was not to be repeated. It was also reasoned that, with further knowledge of the "how" of the digestion process, these problems should become less significant, disappear, or the answers to these problems would become apparent from a rationalization of their cause and effect on the process.

In order to proceed with the next phase of the digestion project, the author was retained as a consultant, in June, 1949, to undertake a study of the process in a pilot plant on a scale large enough to project the practicability of the process to a full-scale installation. A pilot plant incorporating the necessary auxiliary equipment, including heating facilities and metering equipment, was set up at the Iowa City sewage treatment plant and was operated in parallel with the Iowa City digesters. The pilot digestion tank, 6 ft. in diameter and 6 ft. deep, provided an operating capacity of 1,130 gal. and was operated for a period of one year to check the laboratory results previously obtained. It is apparent from the summary results of the year's operation (Table I) that the operation of the pilot plant was successful and that the loadings were considerably higher than those feasible in conventional sewage sludge digestion installations.

Laboratory studies were carried on during and following the pilot studies, in an effort to evaluate the effect of

TABLE I.—Average Results of Pilot-Plant Operation; August 22, 1949, to August 22, 1950

Raw sludge:	
Total solids (%)	7.37
Volatile solids (%)	60.5
pH	5.75
Loading:	
Tot. sol. (lb./day/cu.ft. cap.)	0.464
Vol. sol. (lb./day/cu.ft. cap.)	0.262
Displacement (days)	10.1
Gas production:	
Cu.ft./day	315
Cu.ft./lb. vol. sol. added	8.31
Operating conditions:	
Digester temp. (°C.)	34.9
pH	7.05
Volatile acids (p.p.m.)	317
Digested solids:	
Total solids (%)	5.52
Volatile solids (%)	47.2

the control methods utilized to maintain a favorable biological environment for maximum activity. These studies, carried on in multiple 8-l. laboratory digesters over a period of three years, showed that the required high biological activity of the process could be maintained with a continuous recirculation of diffused digester gas under controlled conditions, and that the coke could be eliminated. These laboratory studies further indicated that the results obtained with the higher rate of recirculation and without the coke would be equivalent to those obtained during the earlier work with the coke and gas. This simplified the operation and considerably reduced the operating cost of the process because of the elimination of the need for the daily addition of coke.

The process as finally developed consists of a biological digestion unit with continuous recirculation of diffused gas through centrally-located gas diffusers (Figure 1), which results in complete gasification of the sludge by circulation of the entire contents, thus bringing the seed sludge, the raw sludge, and the gas into intimate contact while maintaining a uniform, constant temperature in the entire contents of the unit. As in the aeration tank of an

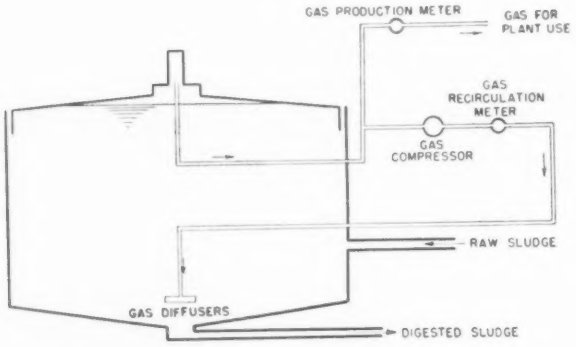


FIGURE 1.—Flow diagram for gas recirculation.

activated sludge plant, the diffusion of gas bubbles near the bottom of the tank results in a uniform lift of the contents over the area of active diffusion and causes a gentle roll of the entire tank contents with upflow at the tank center and downflow at the periphery.

Following the further laboratory development of the process, the pilot plant was again placed in operation, starting in November, 1952, to confirm the laboratory studies and to observe, on the semi-plant scale, the operating problems usually associated with new developments. The pilot plant has been in operation since that time at average loadings as indicated in Table II. For comparative purposes, typical accepted loadings for conventional digestion tanks are also presented. It should be noted that the data for the pilot plant and those by Rudolfs and Fontenelli are for the biochemical phase of digestion only and that allowance for supernatant separation must be made for direct comparison with other data in the table. If necessary, in full-scale installations, supernatant separation can be carried on in supernatant separation tanks or in lagoons. It is apparent that these loadings are at least three times those commonly accepted for the design of digesters and, in fact, are equivalent to loadings heretofore possible only under laboratory conditions.

The successful trouble-free operation of the plant at these loadings has indicated the value of this process as a

TABLE II.—Comparative Digester Loadings with Municipal Sewage Sludge

Item	Dry Solids (lb./cu. ft./day)		Displacement (days)	Capacity (cu. ft./cap.)
	Volatile	Total		
Pilot plant (biochemical only):				
Ten-month average	0.277	0.460	8.7	0.39[1]
Maximum month average	0.345	0.591	7.2	0.30[1]
Optimum loadings for primary digesters[2]	0.1	—	—	—
Ten-State Standards[3]	—	—	—	3.0 to 4.0
Maximum loadings at existing plants[4]	0.067 to 0.157	0.103 to 0.203	—	—

[1] Based on 90 per cent plant removal of 0.2 lb. total suspended solids per capita per day.
[2] According to Rudolfs and Fontenelli (4).
[3] Primary and secondary for standard filter plants (9).
[4] According to Schlenz (10); primary and secondary digestion.

TABLE III.—Summary Data, Laboratory Digestion Project No. 2

Item	Digester Number[1]							
	3	4	7	8	9	10	11	12
Raw sludge and loading:[2]								
Total solids (%)	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91
Volatile solids (%)	59.4	59.4	59.4	59.4	59.4	59.4	59.4	59.4
pH	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70
Tot. sol. (lb./day/cu. ft. cap.)	0.495	0.495	0.495	0.495	0.495	0.495	0.495	0.495
Displacement (days)	10	10	10	10	10	10	10	10
Operating conditions:								
Gas recirc. (cu. ft./day)[3]	38	38	0	0	38	38	38	38
Coke addition (lb./100 gal. raw sl.)	0.42	0.42	0.0	0.0	2.10	2.10	1.05	1.05
No. days operation[4]	96	95	103	106	121	115	121	108
pH	7.19	7.19	7.19	7.18	7.17	7.18	7.17	7.18
Volatile acids (p.p.m.)[5]	388	367	374	388	361	346	349	369
Gas prod. (cu. ft./lb. vol. sol. added)[5]	8.05	8.27	7.12	7.42	7.82	7.64	8.07	7.91
Supernatant:								
Total solids (%)	1.90	1.79	1.93	1.67	2.28	2.25	2.58	2.22
Volatile solids (%)	48.2	49.2	47.0	50.4	46.9	45.4	44.7	45.8
Digested Sludge:								
Total solids (%)[5]	7.38	7.71	7.05	7.26	7.09	7.16	6.94	7.22
Volatile solids (%)[5]	37.6	37.7	38.0	38.5	41.1	40.4	41.2	39.5

[1] Not consecutive because numbers represent incubator positions.

[2] Average for first 120 days.

[3] Cubic feet per day per 1,000 cu. ft. of digester capacity.
Before termination of digestion.

[4] Number of days operation before termination of digestion. Termination arbitrarily set at time volatile acids reached 1,000 p.p.m. for two days or more, as drop in gas production and further rise in volatile acids followed in every case.

[5] Average results up to time of termination.

means for treatment of sewage sludge. The process makes a well-stabilized sludge, as indicated by normal gas production per pound of volatile material added, satisfactory reduction of volatile solids, production of a readily driable sludge, and absence of objectionable odors.

Laboratory Work

As indicated previously, the first pilot-plant operation was carried on to demonstrate the feasibility of a digestion control procedure involving the addition of small amounts of ground coke and recirculated diffused digester gas. Laboratory Run No. 2 was an attempt to evaluate the effect of the addition of the ground coke. Eight 8-l. bottle digesters were used, three pairs with different quantities of coke and one pair with no coke. Raw sludge was taken directly from the Iowa City raw sludge sampling lines. All digesters were operated at 35°C. (95° F.) Sludge or supernatant was withdrawn daily; raw sludge and the recirculated gas were added twice daily. The total volume of raw sludge added daily was equal to one-tenth the volume of the digestion capacity. From the balloon in which it had been collected, the recirculated gas was discharged through a porous diffuser located in the bottom of the digester at a rate sufficient to produce appreciable turbulence in the digester contents. The conditions of operation and significant results are presented in Table III. A similar setup is shown in Figure 2.

Operation of all digesters continued satisfactorily for about 100 days, or for 10 complete displacements. Digestion eventually ceased, however, as indicated by a rapid increase in volatile acids, reduction of gas production, and presence of objectionable odors. This was apparently caused by a major reduction of tank capacity due to accumulation of large volumes of dense solids which were not active in the digestion process. Under these conditions, the actual detention time was far less than 10 days.

The normal volatile acid content of these digestion tanks varied between 200 and 600 p.p.m. The sudden drop in gas production in each case occurred following a sudden rise of volatile acids to 1,000 p.p.m. The possible effect of the carbon addition on the time when gas production suddenly dropped is indicated in Figure 3. The duplicates checked well and there were indications that the coke was of value. However, the control, with no coke and no gas recirculation, did not confirm the trend, so it was concluded that there was no correlation between the termination of digestion due to loss of digester capacity resulting from accumulation of inert solids and the addition of coke.

Laboratory Run No. 3 was carried on to evaluate the effect of the recirculation of different quantities of digester gas. The digesters consisted of ten 8-l. digestion bottles, the same as those used for Run No. 2. The same amount of coke was added to eight of these bottles, various quantities of gas were recirculated to nine bottles, and the tenth was a control. The conditions of operation and pertinent summary data are presented in Tables IV and V. The operating procedure was similar to that used for Run No. 2 except that all digester contents were manually mixed once each week to prevent the accumulation of the large volumes of inert materials apparently responsible for all troubles in Run No. 2, and the raw sludge was screened through ¼-in. mesh. The manual mixing was justified to simulate pilot-plant operation where

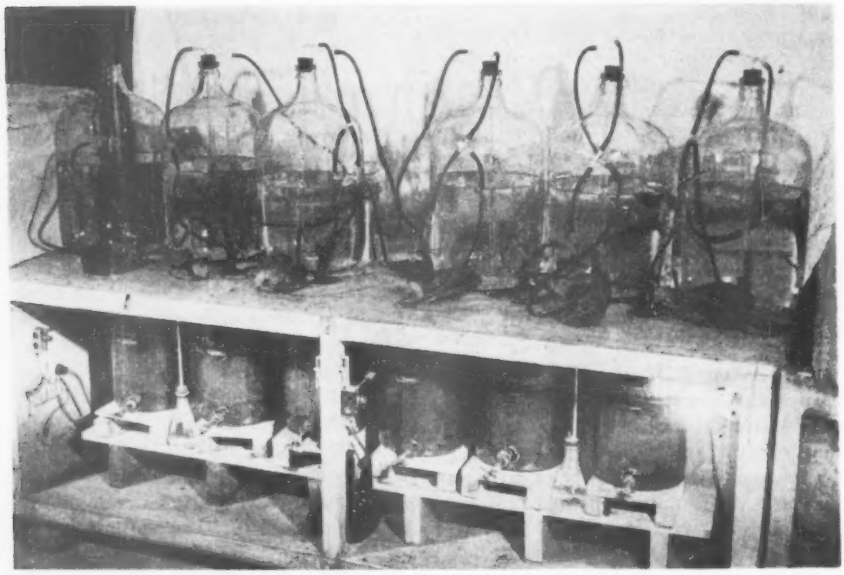


FIGURE 2.—Apparatus used for laboratory study of accelerated digestion of sewage sludge.

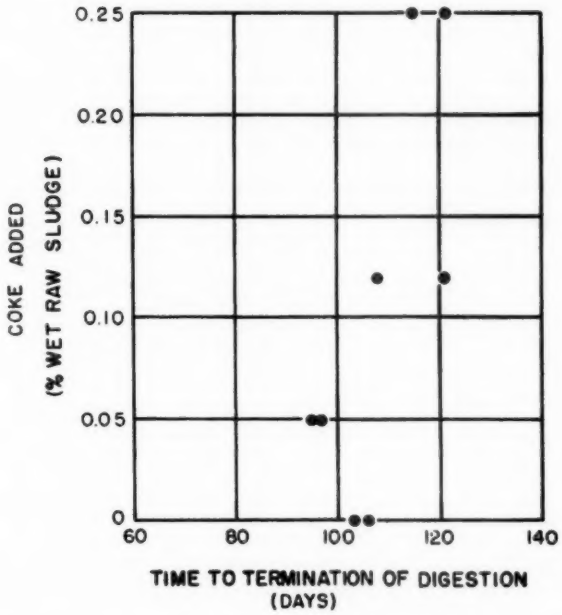


FIGURE 3.—Effect of coke addition on time of termination of digestion, Run 2.

an equivalent amount of gas would result in greater mechanical work on the sludge because of the greater submergence of the diffuser unit.

Operation was satisfactory and all digestion tanks (with the exception of No. 4) operated at the loading indicated in Table IV for 176 days until the run was terminated to start other studies.

During this run each digestion tank developed a temporary increase in volatile acids, which is not recognized as typical of digester operation, but which appeared to be of some significance in this study. In each digester, the volatile acids suddenly increased to a maximum and then dropped. Figure 4 shows these typical volatile acid peaks for digesters No. 1 to 4. The time sequence of the appearance of these peaks apparently followed a pattern which was related to the quantity of gas recirculated in the digestion tanks.

The relationship of these two factors is indicated in Figure 5. The reason for this relationship of the rise in volatile acids and gas recirculation is not obvious, but the possibility that this was a chance relationship is highly improbable with nine separate digestion units following a consistent pattern for 110 days. The significance of these temporary increases in volatile acids likewise is not apparent, but it is not credible that it is due solely to the

TABLE IV.—Average Conditions of Operation, Laboratory Digestion Project No. 3

Item	Operation Period (days)	
	0 to 148	149 to 176
Displacement (days)	10	7
Total solids (%)	7.78	10.15
Volatile solids (%)	58.4	48.1
pH	5.84	5.78
Tot. sol. (lb./day/cu.ft. cap.)	0.486	0.915

TABLE V.—Normal Operating Conditions and Results,[1] Laboratory Digestion Project No. 3

Item	Digester No.[2]								
	1	2	3	4[3]	5	6	7	9	10
Gas recirc. (cu. ft./day/1,000 cu. ft. dig. cap.)	147	59	44	37	29	22	15	41	0
Coke addition (lb./100 gal. raw sludge)	1.05	1.05	1.05	1.05	1.05	1.05	1.05	0	0
Ten-day displacement (0 to 148 days):									
pH	7.06	7.07	7.07	7.10	7.10	7.10	7.12	7.10	7.10
Volatile acids (p.p.m.)	316	321	393	303	315	314	316	292	326
Gas prod. (cu. ft./lb. vol. added)	8.15	8.13	8.27	8.53	8.49	8.20	8.28	8.37	8.23
Digested sludge:									
Total solids (%)	7.58	7.38	7.09	5.82	6.68	6.73	7.02	6.57	6.91
Vol. solids (%)	42.4	42.3	43.7	48.8	44.7	44.9	44.2	43.7	43.1
Seven-day displacement (149 to 176 days):									
pH	7.00	7.06	7.05	—	7.03	7.05	7.07	7.08	7.10
Volatile acids (p.p.m.)	286	284	241	—	366	244	303	270	298
Gas prod. (cu. ft./lb. vol. added)	6.51	6.07	6.77	—	6.60	6.43	7.34	6.88	7.08
Digested sludge:									
Total solids (%)	8.70	8.55	8.64	—	8.60	8.61	9.29	8.52	8.66
Volatile solids (%)	37.1	36.7	36.0	—	36.6	35.6	35.7	36.0	35.2

[1] Data for each digester is average of all data for 176 days run except for omission of one 20-day period (10 days preceding to 10 days following date shown in Figure 5). This 20-day period is not representative of normal operation.

[2] Digester No. 8 started, but after 75 days of successful operation it was converted to other studies.

[3] Data for first 90 days. Digestion failed at 100 days, operation discontinued at 126 days.

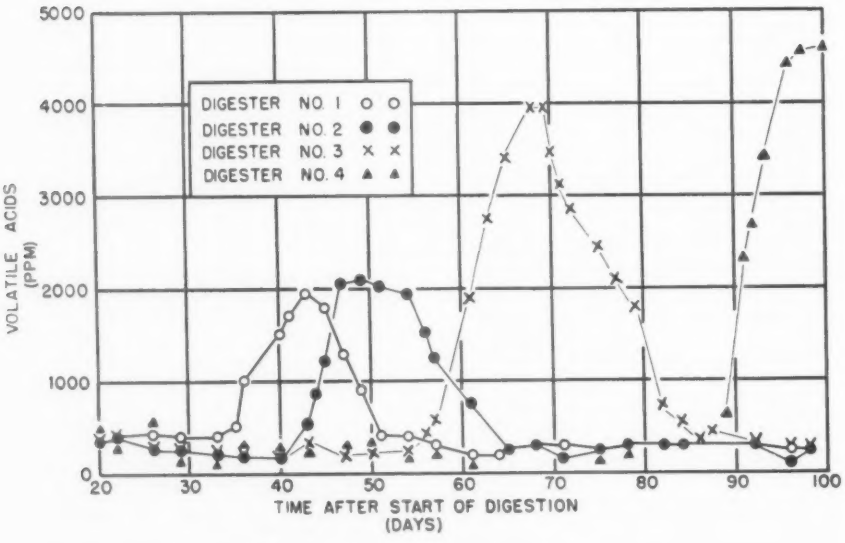


FIGURE 4.—Typical volatile acid curves, Run 3.

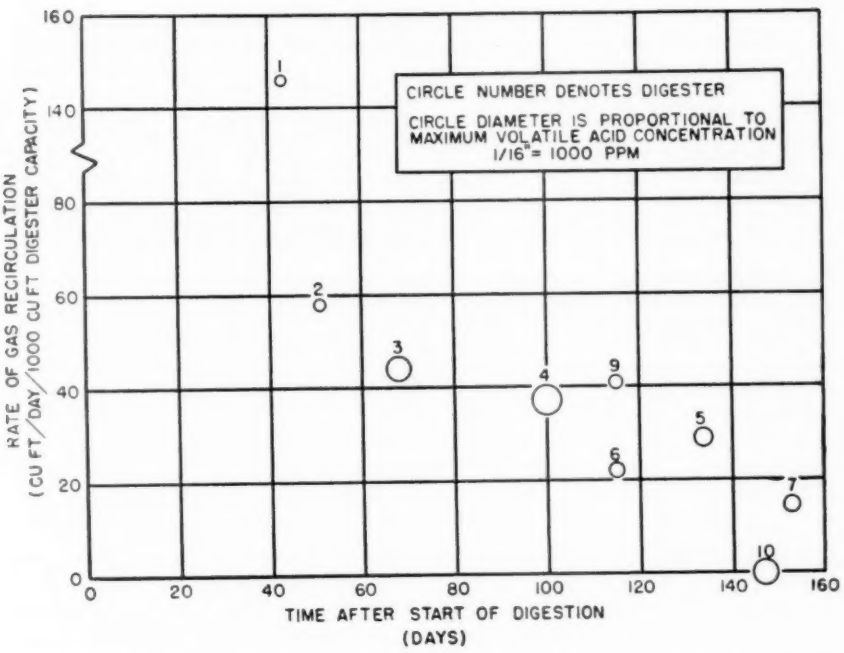


FIGURE 5.—Effect of gas recirculation rate on time of development of temporary maximum volatile acid concentration.

mechanical mixing action of the gas added because, during this 110-day period after the first temporary increase, all digesters were thoroughly mixed manually some 16 times. The fact that all digesters resumed normal operation after the temporary increase in volatile acids (with the exception of No. 4) indicated that some sort of a transition, which would acclimate the sludge to the higher loadings, was taking place in the digesting material. Digester No. 4, in all probability, would have recovered also except for the fact that just as its recovery started on the 103rd day of digestion, the loading temporarily increased to 1.0 lb. total solids per cubic foot per day for a period of two days and averaged 0.73 lb. per cubic foot per day for the following 11-day period.

It is interesting that the displacement was reduced to seven days for the last 28 days of operation and during this period the average loading was 0.915 lb. total solids per cubic foot per day and 0.440 lb. volatile solids per cubic foot per day. The high ash content of the raw sludge during this period was the result of a wet-weather period with high surface runoff. No adverse effect of this high solids loading was evident and digestion was entirely satisfactory at the termination of this experiment. There was no indication that the digesters could not be operated at even higher loadings.

The results of this run with the very high loadings provided ample justification for continuing the project to develop methods for operating full-scale digesters under similar conditions.

Laboratory Run No. 4. was carried on to further evaluate the effect of gas recirculation and, in particular, to study the effect of gas recirculation

TABLE VI.—Summary Data, Laboratory Run No. 4

Item	Digester Number						
	1	2	3	5	6	7	8
Raw sludge loading:							
Two solids (%)	7.72	7.57	7.72	7.57	7.75	7.72	7.72
Volatile solids (%)	58.3	59.2	58.3	59.0	58.2	58.3	58.3
pH	5.77	5.71	5.77	5.75	5.70	5.77	5.77
Tot. sol. (lb./day/cu. ft. cap.)	0.482	0.473	0.482	0.473	0.484	0.482	0.482
Operating conditions:							
Gas recirc. (cu. ft./day/1,000 cu. ft. cap.)	12,000	524	142	42	0	142	142
Coke addition (lb./100 gal. raw sludge)	0	0	0	0	0	0.52	1.05
Duration of run (days)	276	191	276	232	164	276	276
pH	7.17	7.17	7.15	7.14	7.18	7.14	7.13
Volatile acids (p.p.m.)	363	363	333	327	356	317	350
Gas prod. (cu. ft./lb. vol. sol. added)	8.15	8.28	8.31	8.36	8.38	8.41	8.21
Digested sludge:							
Total solids (%)	6.10	6.24	6.53	6.44	6.47	6.48	6.64
Volatile solids (%)	44.2	43.9	43.6	44.0	43.3	43.8	44.3

rates without the addition of coke and with continuous recirculation. The setup and operating procedure for this run were the same as that for previous runs except that a small gas pump was utilized to provide continuous gas recirculation for Digester No. 1. In six digesters, various quantities of gas were recirculated and no coke was added; both coke and gas were added to two as a control. The quantity of gas recirculation to each digester was equal to or greater than the maximum rate utilized in the previous run in all digesters except No. 4 and No. 5. No. 4 was taken over for other studies after 53 days of operation so cannot be considered part of this study. The condition of operation and pertinent summary data are presented in Table VI.

The temporary increase in volatile acids or the so-called transition took place in No. 8 at 148 days and in No. 6 at 173 days, but was not apparent in the other tanks. This means that the transition was reproduced in the control, without gas recirculation, at 173 days as compared to 146 days in the previous run. The transition in No. 8 at 148 days was late compared with 41 days for equivalent rates of gas recirculation in the earlier run. The other digesters did not develop the typical transitions, although No. 1 and No. 2 might not be expected to because of the higher rates of gas recirculation, but No. 3, No. 5, and No. 7 definitely failed to confirm the action expected as a result of performance in the previous run.

After 3½ months of normal operation (106 days) in all digesters, the manual mixing was discontinued to discover whether the effects of the gas recirculation would be more apparent. At 165 days, the gas production from No. 6 (without gas recirculation) suddenly dropped to between 30 and 60 per cent of normal and continued at this low rate for 25 days, but with no apparent increase in volatile acid content of the digesting sludge. During this time, however, there was a heavy top scum in this digester and sampling of the scum and bottom sludge indicated that the raw solids were accumulating in the scum and were not being digested (Table VII). This apparently was a typical example of an overloaded conventional digester. After collecting the samples, the entire contents were

manually mixed and the following day the volatile acids rose to 4,620 p.p.m., active foaming took place, and all digestion failed.

Digester No. 6 failed because no gas circulation was provided and raw solids with insufficient seed material accumulated in the top of the bottle. Twenty-seven days after the failure of gas production in No. 6, a similar failure took place in No. 2. Forty-one days after this second failure, No. 5 failed. At the conclusion of the test, at 277 days, digesters No. 1, 3, 7, and 8 with gas recirculation were operating normally.

All digesters had operated satisfactorily with gas recirculation and weekly manual mixing. When manual mixing was discontinued, No. 6, without gas recirculation, failed first. No. 5 with only a very small amount of gas recirculation also failed. The failure of Digester No. 2 appears to contradict the indicated conclusion that all bottle digesters will operate successfully with adequate gas recirculation. This abnormality can be explained, however, when the method of diffusing the gas is examined. Because of the large volume of gas recirculated to digester No. 2, a balloon that was larger than that used for the other digesters was necessary. This larger balloon (volley-ball bladder) had a small outlet so the rate of gas addition was very small and little gas contact was accomplished. The gas "piped" itself through the sludge in the bottle without developing any circulation of the tank contents. With the small balloons, the outlet was larger and the gas was discharged at a high rate with a resultant satisfactory gasification.

This run demonstrated the importance of satisfactory gas recirculation and further indicated, by the operations of No. 1, that continuous recirculation of digester gas would accelerate the digestion process.

TABLE VII.—Analysis of Digester Contents No. 6 After 186 Days of Operation

Item	Heavy Top Scum	Bottom Contents
Tot. solids (%)	14.5	1.74
Vol. solids (%)	65.2	49.7
pH		7.45
Vol. acids (p.p.m.)	7830	740

Mechanics of Gas Diffusion

The effectiveness of digester gas diffusion to accelerate digestion has been demonstrated. The importance of adequate gasification to operate a digestion tank at high solid loading rates was likewise demonstrated.

The experience gained during these studies established the general range of gas contact requirements. In order to project these requirements to full-scale digester operation, the mechanics of providing adequate gas diffusion to bring about intimate and uniform contact of the diffused gas with the sludge particles had to be worked out.

Consideration was given to the shape of the tanks, including other than circular tanks, as well as the point of application of the gas for all probable digestion tank shapes. It was decided, however, that this study should be limited to circular tanks for reasons of their economy and standardization.

Model studies were carried out to establish the mechanics of application. The model utilized was a flat-bottom tank 4 ft. deep and one quadrant of a circle in plan, with a 4-ft. radius Measurements of travel of bubbles, velocities, and rates of diffusion were made.

Diffusion at the center and near the bottom for circular tanks was established to provide the maximum gas-sludge contact.

Data were developed from this model tank, with gas diffusion at the center and near the bottom, to project the gas content requirements for full-scale cylindrical digesters. These studies led to development of a criterion for de-

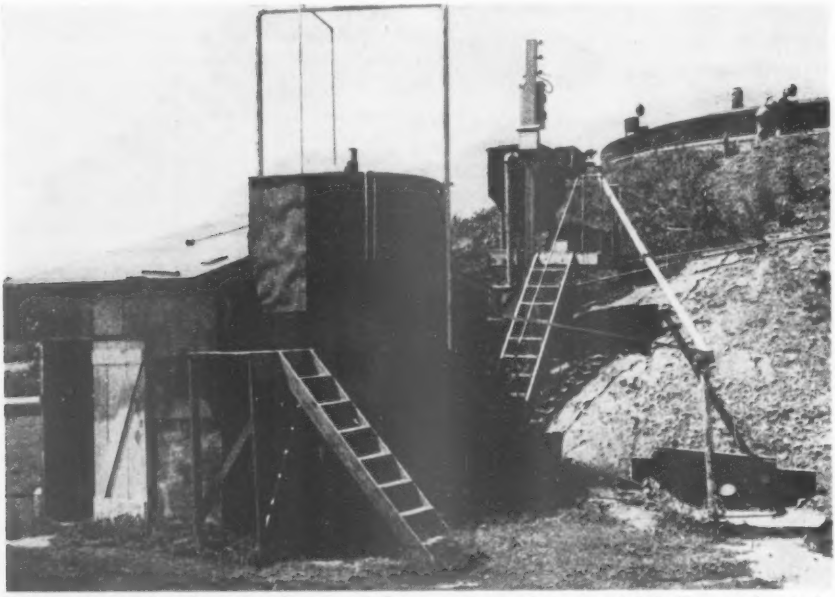


FIGURE 6.—Pilot plant, showing raw sludge metering tank (upper right), digester (center), and control house (left) containing gas recirculation and metering equipment.

termining the quantity of gas required for cylindrical digesters of various diameters.

This projection was checked within a satisfactory range by operation studies in a full-sized digester 70 ft. in diameter and 25 ft. side water depth at the Columbus, Ohio, sewage treatment plant.

Location of the gas diffusers at the center of the tank and near the bottom also provide for simplest withdrawal of the diffusion unit through an opening in the top of the tank; minimum piping; and deposition of separated, excessive grit that has not been previously removed in the plant process. If such grit deposition is of excessive volume, deposition will take place in the bottom cone under the diffuser unit, where it is removed through the sludge withdrawal pipe during normal withdrawal of the digested sludge.

Pilot-Plant Operation

As indicated previously, additional operation of the pilot plant was necessary, following the laboratory work on the effectiveness of gas recirculation, to confirm the laboratory results on a semi-plant scale and to experience operation problems which are expected in any new development.

The complete pilot-plant installation (Figure 6) consisted of the raw sludge metering tank, the digestion tank, and a control building, housing the gas recirculation and metering equipment. The metering tank received raw sludge direct from the Iowa City raw sludge line. The volume of raw sludge was determined by depth measurements. Samples for analysis were collected after a 20-sec. period of aeration, which provided a thorough mixing of the entire contents. The raw sludge flowed by gravity into the digester.

The digester, a steel tank 6 ft. in diameter and 6 ft. deep with a dished bottom providing an additional 6-in. depth at the center, had a normal operating capacity of 1,130 gal. Although supernatant drawoff lines were provided, they were not ordinarily used

TABLE VIII.—Pilot-Plant Operation 1952–53

Item	Month									
	Nov.[1]	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Raw sludge:										
Total solids (%)	7.48	5.24	4.95	6.60	5.94	5.38	6.89	6.93	6.15	5.62
Volatile solids (%)	60.8	67.7	71.3	57.8	61.5	62.5	56.9	61.2	59.8	67.8
pH	5.72	5.79	5.85	5.88	5.68	5.79	5.92	5.33	5.57	5.58
Loading:										
Tot. sol. (lb./day/cu.ft. cap.)	0.464	0.332	0.356	0.513	0.364	0.447	0.572	0.591	0.542	0.432
Vol. sol. (lb./day/cu.ft. cap.)	0.271	0.223	0.253	0.281	0.220	0.277	0.302	0.345	0.315	0.288
Displacement (days)	10.0	9.8	8.9	8.0	11.8	7.7	7.7	7.5	7.2	8.8
Gas production:										
Cu.ft./day	312	312	335	356	229	344	363	393	419	401
Cu.ft./lb. vol. sol. added	8.42	9.72	9.24	8.90	7.20	8.55	8.66	7.80	9.80	10.2
Operating conditions:										
Digester temp. (°C.)	33.8	33.3	32.4	32.5	33.0	31.9	32.7	36.2	35.9	35.2
pH	7.07	7.10	7.05	6.90	6.62	6.82	6.74	6.82	6.94	6.95
Volatile acids (p.p.m.)	355	375	226	260	1,375	451	270	331	252	195
Gas recirc. (c.f.m., free gas)	2.00	2.18	2.29	1.90	1.68	1.69	—[3]	1.10[2]	1.92	2.23
Digested sludge:										
Tot. sol., side outlet (%)	4.82	3.29	2.90	3.77	4.08	3.50	4.54	4.33	4.49	3.58
Tot. sol., bottom outlet (%)	5.50	4.40	4.30	5.17	5.96	4.22	6.55	5.97	5.74	4.93
Vol. sol., side outlet (%)	49.3	48.8	55.5	47.0	45.8	49.0	44.7	46.3	44.8	52.0
Vol. sol., bottom outlet (%)	48.2	48.7	54.7	45.5	44.1	47.3	41.7	44.0	41.8	51.1

[1] Starting November 12, 1952.
[2] Circulation meter not operating May 1 to June 13; data shown average after June 13.

as such because the solids were distributed uniformly throughout the tank. Gas was collected by a conventional floating cover, and was piped to the recirculation pump and to the production meter. From the booster pump, the recirculated gas passed through a gas filter, through the recirculation meter, and into the digestion tank through a 1-ft. long precision diffuser tube located 1 ft. off the bottom in the center of the digestion tank. A gas recirculation rate of about 1 to 2 c.f.m. was selected as desirable for this installation, but other rates were used at various times to observe operation. The digesting temperature was maintained at 95° F. with heating coils in the digester, which during the early part of the work were supplied with hot water from the Iowa City boiler, but later were connected to a separate gas-fired hot-water heater.

Under normal operation the digested sludge was withdrawn once daily, with continuous sampling during withdrawal, and raw sludge was added in two equal increments. Solids samples for analysis were composited over 2-day periods. Volatile acids determinations were made on single samples twice a week or oftener. Data obtained on the operation of the pilot plant for this 10-month run are summarized in Table VIII.

During the early part of the run, the raw sludge was fed at a rate which resulted in a 10-day displacement. Operation was entirely satisfactory, as indicated by all the control tests available, by the usual observations of the sludge, and by gas production.

The loading was then gradually increased until the displacement period was reduced to 7 days; operation was maintained at this loading for the remainder of the run. The long period of operation at the high loading, resulting from operation at the 7-day displacement rate, indicated the stability of the process under these loadings. Several temporary interruptions to normal operation, due to mechanical breakdown of the gas recirculation pump, inadequate heating before the installation of the unit hot-water heater, and other minor mechanical problems, indicated that the operation was rugged and not too sensitive for practical operation even at these load-

ings. On several occasions following periods of non-normal operation, an operating problem was indicated by a temporary frothing or bulking of the sludge, but was immediately controllable. In no case was the operation uncontrollable, a further indication of the stability of the process. Typical foaming problems with accompanying high volatile acids did not develop at any time as would be expected with these loadings in conventional digestion tanks.

The question of the driability of the sludge following the short-time digestion was investigated during the summer of 1953. Six sludge drying beds (Figure 7), each 3 ft. by 3 ft., were built in one of the Iowa City drying beds and were filled at two-week intervals by pairs. In each pair one bed was filled with pilot-plant sludge and the opposite bed with Iowa City sludge, all to a depth of 11 in. Drying rates, as indicated by the drop in the sludge level and the time required for cracking to the sand, were observed. The pilot sludge dried in every case as fast or faster than the Iowa City sludge, which had been subjected to a digestion period in excess of 50 days. Although in a full-scale plant the short-time digestion sludge would be concentrated in a secondary tank or supernatant separator before being discharged to sludge beds, this series of drying tests is indicative of drying characteristics of the sludge because further storage and concentration would, if anything, improve the drying characteristics.

Analyses of the pilot-plant gas and the Iowa City digester gas were made once a week during the last two months of the run. The average carbon dioxide content of the pilot-plant gas during this period was 36.5 per cent, as compared with 34.5 per cent for the Iowa City plant gas. If one day's analyses are omitted, the average CO_2 content of the pilot-plant gas was 35.5 per cent, as compared with the same average of 34.5 per cent for the Iowa City gas.

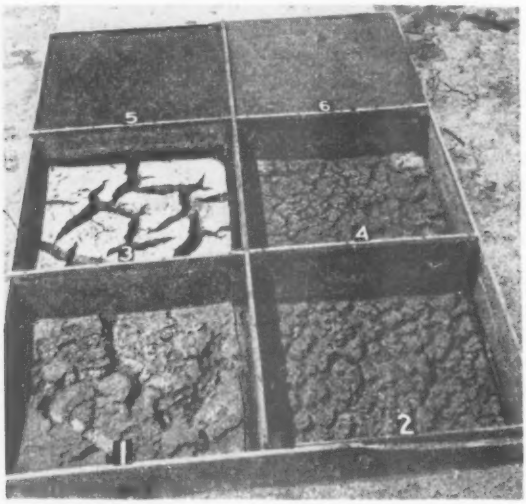


FIGURE 7.—Experimental sludge drying beds. Even numbered beds contain pilot-plant sludge, odd numbered beds contain Iowa City sludge. Beds 5 and 6 have just been poured, beds 3 and 4 have been drying for 14 days, and beds 1 and 2 have been drying for 28 days.

Application to Full-Scale Operation

The long-time operation of the laboratory and pilot-plant digesters has indicated that the process will provide a reliable method for digesting sewage solids in a fraction of the time utilized by the conventional digestion process. The complete separation of the biological phase from the mechanical phase of the process of liquid and solids separation, and the establishment of an environment for high bacterial activity throughout the complete digestion unit, has made possible this accelerated process.

Conventional empirical design capacities, which provide for scum accumulations and for bottom solids separation and possible loss of control because of these unavoidable accumulations of solids, will not apply to the design of tanks utilizing this process. With this process, the digestion unit should be designed on the basis of allowable solids loading, independent of the method of ultimate disposal of the sludge. Thus, the secondary unit or supernatant separator can be designed on the basis of accepted requirements for satisfactory separation and sedimentation, with due consideration to the method of ultimate disposal. If seasonal storage is required, it should be considered in designing the secondary unit only.

Although the pilot plant was operated at monthly average loadings up to 0.345 lb. of volatile solids per day per cubic foot, it is recommended that until further field data are obtained full-scale installations be designed for not more than 0.20 lb. of volatile solids per day per cubic foot to allow for seasonal variations in raw sludge production and quality of solids. For existing plants, loadings greater than 0.20 lb. volatile solids per day per cubic ft. may be used on the basis of the opportunity of developing an objective loading rate by preliminary operation in one tank.

A full-sized digestion tank at the Columbus, Ohio, plant has been converted for operation in accordance with this process. This installation is being operated under the supervision of Superintendent James H. Blodgett. The operating results from this plant are providing confirmation of the laboratory and pilot-plant work.

Conclusions

A sludge digestion process has been developed for the biochemical phase of digestion which makes it possible to complete the anaerobic decomposition of sewage solids in approximately one-third of the time currently considered necessary.

Laboratory and pilot-plant operations during a period of more than four years have indicated that sewage sludge can be digested at loading rates of 0.345 lb. of volatile solids per day per cubic foot of digester volume and at tank displacement periods of 7.2 days.

This process produces a well-stabilized sludge, as indicated by normal gas production per pound of volatile solids added, satisfactory reduction of volatile solids within established standards, production of a readily driable and filterable sludge, and the absence of objectionable odors.

This accelerated sludge digestion process requires the recirculation of diffused gas throughout the digester contents to bring the seed sludge, the raw sludge, and the gas into intimate contact. Uniform temperature in the digester is maintained at approximately 95° F. Gas diffusion is accomplished through centrally located gas diffusers placed near the bottom of the digester.

Laboratory and pilot-plant observations of this process have shown the absence of blankets of digestible material commonly considered as part of the scum at the top of the digester.

Excessive grit in the sludge is eliminated as a problem by separation and deposition in the cone of the tank, where it can be removed through the sludge withdrawal pipe.

The mechanical phase of sludge digestion (supernatant separation and sludge storage) can be effectively and economically accomplished in a separate tank or in digested sludge lagoons.

Operating results from the full-scale operation at the Columbus, Ohio, plant have confirmed the laboratory and pilot-plant studies. It is recommended that, until further field data are obtained, full-scale installation be designed for 0.2 lb. of volatile solids per day per cubic foot. Higher loadings may be utilized at existing plants on the basis of the opportunity of developing an objective loading rate by preliminary operation in one tank.

Acknowledgments

The work reported herein was supported by the Chicago Pump Company and was carried out with the active cooperation of Milton Spiegel, Miles Lamb, J. J. Klein, and T. H. Forrest, all of the company's staff.

The experimental work was carried on at the Iowa City sewage treatment plant with the active cooperation of Superintendent M. F. Neuzil, his staff, and the city officials who made it possible to make use of the city's facilities.

The daily work was supervised and carried on consecutively by Harold E. Schmidt, Edwin D. Simmons, and Peter J. Neuspiel working on full-time basis under the author's general direction. They were assisted by part-time student employees throughout the period of the studies.

References

1. Keefer, C. E., and Kratz, H., "The Digestion of Scum From Preliminary Settling Tanks." *Sewage Works Jour.*, **3**, 1, 50 (Jan., 1931).
2. Fair, G. H., and Moore, E. W., "Time and Rate of Sludge Digestion and Their Variation With Temperature." *Sewage Works Jour.*, **6**, 1, 3 (Jan., 1934).
3. Heukelekian, H., and Kaplovsky, A. J., "Effect of Change of Temperature on Thermophilic Digestion." *Sewage Works Jour.*, **20**, 5, 806 (Sept., 1948).
4. Rudolfs, W., and Fontenelli, L. J., "Relation Between Loading and Supernatant Liquor in Digestion Tanks." *Sewage Works Jour.*, **17**, 3, 538 (May, 1945).
5. Hyde, C. G., "Gas Collection and Utilization." *Sewage Works Jour.*, **16**, 6, 1221 (Nov., 1944).
6. Wilt, W. D., "The Practical Side of Safety." *Sewage Works Jour.*, **16**, 4, 687 (July, 1944).
7. Rawn, A. M., "Automatic Sludge Stirring Mechanisms." *Sewage Works Jour.*, **3**, 1, 24 (Jan., 1931).
8. Keefer, C. E., and Kratz, H., "The Effect of Gases on Sewage Sludge Digestion." *Sewage Works Jour.*, **4**, 2, 247 (Mar., 1932).
9. Upper Mississippi River Board of Public Health Engineers and Great Lakes Board of Public Health Engineers, May, 1952.
10. Schlenz, H. E., "What You Should Know About Sludge Digestion." *Pub. Works*, **82**, 10, 67 (1951).
11. Spiegel, M., Lamb, M., and Klein, J. J. Unpublished data.

DISCUSSION

By James H. Blodgett

Superintendent, Sewage Treatment Plant, Columbus, Ohio

The first practical and full-scale application of the findings discussed in this paper in connection with accelerated sludge digestion was entered into by the City of Columbus without precedent in full-scale operating experience. Although extensive experiments with this process had been run on the sludge

at this plant, and although these experiments developed a remarkable record of heavy tank loadings, they still were on a laboratory scale, easily controlled and observed and subjected to expert technical supervision and operation.

It was quite another matter to expand these experiments to a full-scale installation, with the usual interruptions, delays, errors in judgment by non-technical employees, and other unforeseen situations normally to be expected in sewage plant operation.

However, necessity of taking some action on an increasingly difficult overloading problem with respect to sludge digestion capacities required that a solution be found. The economy of being able to utilize what was available with slight modifications in operational procedures vastly out-weighed the estimated additional cost of constructing conventional facilities for this purpose. It was quite natural, therefore, to try out the experiment on a full-scale basis.

The process was selected to be run in one of the battery of eight fixed-cover digesters, which have a diameter of 70 ft., a maximum sidewall water depth of 25 ft., with a conical bottom 8 ft. deep. The total volume of the tank is 106,000 cu. ft. This tank is heated by hot-water coils supported on the walls.

Necessary modifications consisted of moving the gas drawoff line out of the center and to the side of the gas dome, rearranging the raw sludge inlet piping to permit installation of the gas diffusion equipment and two gas pipe connections, and installing two observation ports and a float alarm arrangement in the gas dome.

Some doubt was expressed as to the proper amount of gas diffusion required to create desired gas contact and tank turnover, so it was suggested and agreed that tests be run in the tank filled with clear water and using air with the proposed diffusing equipment. Observations were made to make sure that the equipment to be used was adequate and that the projections to the full-scale installation of the gas contact data developed in the model studies were correct.

The results of the full-scale tests closely substantiated the findings made on the pilot-plant scale. Therefore, having established the rate of gas diffusion necessary, the unit was closed up and the process placed in operation.

Starting with the tank two-thirds full of seeded digesting sludge, loading was at the rate of 8,400 lb. of dry total solids per day during the first week, this being equivalent to 2.4 lb. per cubic foot of maximum tank capacity per month. The second week this was stepped up to 11,000 lb. of dry solids per day, equal to 3.15 lb. per cubic foot of maximum tank capacity per month. During the third week this loading was increased to 22,000 lb. per day, equivalent to 6.30 lb. per cubic foot of tank capacity per month. Thereafter, an average loading of 30,300 lb. per day or 8.58 lb. per cubic foot per month of maximum tank capacity was added and there it has been maintained.

The average analyses of the first four months of operation, upon which this report is based, showed a raw sludge of 59.75 per cent volatiles digested to 50.2 per cent volatiles.

Raw sludge total solids averaged 6.6 per cent, whereas digested sludge solids ran 4.6 per cent. Gas production from this unit was carefully metered and averaged 128,100 cu. ft. per day, which is equivalent to 4.3 cu. ft. per pound of solids added and 7.1 cu. ft. per pound of volatiles added, or 19.1 cu. ft. per pound of volatiles destroyed.

Circulation of gas was maintained at 76 c.f.m., the quantity found necessary as a result of the full-scale tests, and the tank temperature was held between 84° and 90° F. during this period.

Comparison of these results with the loadings and records of operation

of conventional sludge digestion tanks in the Columbus plant over a period of several years, shows that the average loadings have been 3.02 lb. of total solids per cubic foot of maximum tank capacity per month, with a volatile content of 64.7 per cent reduced to 54.4 per cent, in an average detention period of 26 days and at comparable temperatures.

With an average of 6.6 per cent solids in the sludge fed to the test tank and a loading of 30,300 lb. of solids per day, 55,200 gal. of sludge per day has been sent to the unit. This indicates 14.4 days or 55 per cent of the detention time in the conventional tanks and at a loading rate 275 per cent of that at which the conventional tanks have been operated.

Table I gives the average daily loadings on the digester. This tabulation is broken down into averages based on the full 128-day period of operation, and the maximum day's loadings. Table II summarizes the average daily data based on 128 days of operation.

Digester sludge from the process, although slightly higher in moisture content than that removed from conventional digesters, proved equally amenable to vacuum filtration. The percentage of conditioning chemicals used was, for all practical purposes, the same; the pounds of dry solids per square foot of filter area per hour and moisture content of the filter cake were closely comparable.

TABLE I.—Digester Loading Data

Item	128-Day Average[1]	Maximum Day[2]
Raw sludge (g.p.d.)	55,200	81,600
Total solids:		
Pounds	30,300	76,500
Lb./cu.ft./mo.	8.58	21.6
Lb./cu.ft./day	0.286	0.725
Volatile solids:		
Per cent	59.75	43.6
Pounds	18,100	33,400
Lb./cu.ft./mo.	5.10	9.45
Lb./cu.ft./day	0.171	0.315

[1] March 14 to July 19, 1953.
[2] July 2, 1953.

TABLE II.—Summary of Digester Operation, Average Daily Data

Item	Total Solids (lb.)	Vol. Solids (lb.)
Raw sludge to digester	30,300	18,100
Dig. sludge from digester	22,850	11,400
Reduction	7,450	6,700
Gas production:		
Total (cu.ft./day)	128,100	
Cu.ft./lb. vol. sol. added		7.1
Cu.ft./lb. vol. sol. destroyed		19.1

These facts seem to have proven the practicability of accelerated sludge digestion by means of gas diffusion to bring the seed sludge, raw sludge, and gas into intimate contact. The research involved and the development of the process seems a worthwhile contribution to the field of sewage treatment where reduction of sewage solids by digestion is practiced.

Experience with the operation of the process has shown the need for some further studies to accomplish satisfactory concentration of the digested sludge. Also, some modification of the installation seems advisable to provide a simple suitable means of removal and replacement of the diffusion unit when necessary. The effect of higher tank temperatures on the process, possibly in the thermophyllic range, remains to be investigated and the volatile acids content as a means of indication and control is to be studied further.

Continuation of the operations in the one tank now in service is being carried on while these and other phases of the process are being studied and perfected. It is expected that further information on the findings will be publicized from time to time.

HIGH-RATE DIGESTION OF CONCENTRATED PRIMARY AND ACTIVATED SLUDGE *

By Wilbur N. Torpey

Senior Civil Engineer, Dept. Public Works, New York City, N. Y.

At the Bowery Bay sewage treatment plant in New York City a new procedure for thickening combined primary and secondary sludges has been carried on since December, 1951. As a result of the use of this method, marked reductions in the volume of raw sludge added to the digesters have been achieved. An opportunity has thus been afforded to operate a digestion tank at solids loading rates considerably higher than current practice. The results of over one year's operation of the digestion tank during which time both the modified aeration and activated sludge treatment processes were being employed, are presented herewith.

The Bowery Bay plant is a step aeration activated sludge plant, at present designed for a flow of 40 m.g.d. This plant employs 1-hr. primary sedimentation followed by 2.5 hr. of aeration and 1.7 hr. of final sedimentation, based on design flow plus 25 per cent return sludge. During 1952, sewage flow to the plant approximated the design rate and the sewage, which is essentially domestic, contained 150 p.p.m. of suspended solids and 165 p.p.m. of B.O.D. Two circular thickening tanks 50 ft. in diameter, each having a picket fence sludge thickening and collecting mechanism, have been provided for concentration of excess activated sludge.

This plant has been operated using two different aeration processes. As designed—for the step aeration process—primary effluent is admitted to the aeration tanks through the step gates, which control the activated sludge concentration. The suspended solids concentration normally averages 2,500 p.p.m. through the four passes of the aeration tank, with the first pass containing about 4,000 p.p.m. and decreasing until about 1,000 pp.m. is reached in the fourth pass. This method may be expected to require a like amount of air, result in the formation of an equal volume of excess activated sludge, and produce the same treatment efficiency as does the conventional activated sludge process, but requires about one-half the aeration tank capacity. The plant has also operated using the modified aeration process, otherwise known as the high-rate activated sludge process. The flow pattern is similar to conventional activated sludge operation, wherein the primary effluent and the return sludge flow together through the entire course of the aerator. The concentration of solids in the aeration tanks is considerably lower, being in the order of 200 p.p.m. There is a decrease of treatment efficiency compared to the step aeration or conventional activated sludge process. Air requirements are reduced by roughly one-half, however, and the modified aeration solids are more amenable to compaction.

The plant includes four circular digesters, each equipped with gas holder covers. The tanks are 81 ft. in diameter at the bottom, increasing to 82.5 ft. above the gas holder ledge. The overall sidewall depth is 33.5 ft.; however,

* Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953.

the sludge level is usually maintained 2 ft. below the top of the wall. Including the conical bottom, which has a depth of 9 ft., the volume of each digester is 180,000 cu. ft. The gross digester volume is, therefore, 720,000 cu. ft., representing 2.1 cu. ft. per capita for an estimated connected population of 350,000.

Sludge is admitted to the digester at the center a few feet below the liquid surface and is removed through the supernatant drawoffs in the upper half of the tank or from the center of the conical bottom by means of the digested sludge line (Figure 1). The digester contents are heated by internal hot-water coils.

These tanks are normally operated using two-stage digestion. The two primary units receive the raw sludge feed on alternate days, the high-level liquor being displaced to the secondary digestion tanks, where supernatant is separated and some additional gas is produced.

The Bowery Bay plant operated on the activated sludge process during parts of 1947 and 1949. In 1947, all the primary and thickened excess activated sludges were pumped to the digestion system. The volume of sludges increased until, during the summer, the total averaged 28,000 cu. ft. per day and the over-all digester detention period was reduced to less than 26 days. At this loading, the concentration of solids in the upper supernatant and the lower zones became almost equal, at approximately 2.3 per cent solids. It became necessary to remove digested sludge at the same rate as the raw sludge was being added, as no supernatant liquor was formed. These tanks were of no advantage in reducing the volume of digested sludge for ultimate disposal. On the other hand, gas production was in the normal range and averaged more than 300,000 cu. ft. per day. To digest the 28,000 cu. ft. of sludge per day and obtain a reasonable reduction in sludge volume, it was apparent that a digestion system considerably larger than the present one would be required.

In 1949 it was decided, on the basis of the 1947 experience, to limit excess activated sludge addition to the digesters to that quantity which would permit securing a reasonable rate of release of supernatant liquor of acceptable quality. The average quantity of excess activated sludge added to the digesters was only 4,400 cu. ft. per

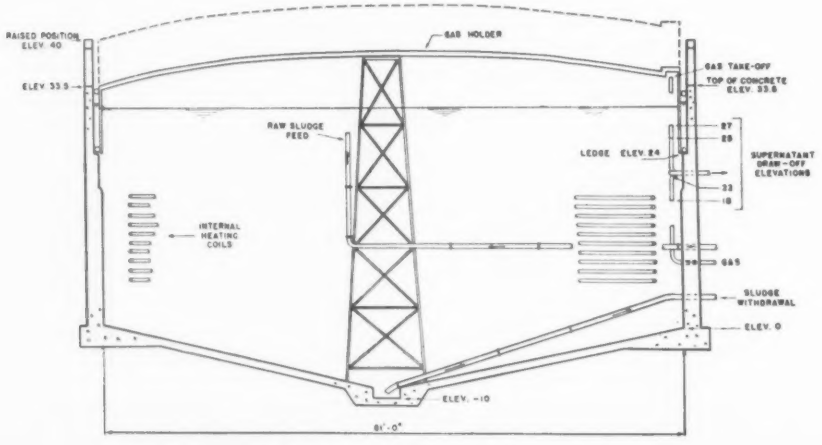


FIGURE 1.—Schematic diagram of digester No. 4.

day, which, in addition to the primary sludge volume of 10,500 cu. ft. per day, resulted in a displacement period of 48 days. The remainder of the excess activated sludge was carried directly to sea in the raw state. Of the total pumpage to the digesters of 14,900 cu. ft. per day, 8,000 cu. ft. of acceptable quality supernatant was removed, leaving 6,900 cu. ft. of digested sludge to be transported to sea per day. By such a procedure the digesters were shown to be capable of handling all the primary sludge plus about one-third of the excess activated sludge.

During 1951, with the plant employing the modified aeration process of treatment, approximately 7,800 cu. ft. per day of primary sludge and 5,500 cu. ft. per day of excess modified aeration sludge was digested. At a displacement period of 54 days, 65 per cent of the raw sludge volume was decanted as supernatant liquor while the remaining 35 per cent was disposed of at sea. An average of 287,000 cu. ft. of gas was produced daily. At this loading of primary and modified aeration sludges, the performance of the four digesters was quite satisfactory.

Therefore, it had been demonstrated that the 2.1-cu. ft. per capita digestion system was adequate for digesting and reducing the volume of the full plant sludge pumpage when the modified aeration treatment process was employed. When activated sludge treatment was used, however, the primary sludge and only one-third of the activated sludge was the maximum load that could be imposed on the four digesters if reasonable reduction in sludge volume was to be obtained.

In December, 1951, a new procedure for thickening raw sewage sludge was started at the Bowery Bay plant with the objective of significantly reducing the volume of sludge added to the digesters. The primary and excess modified aeration sludges were combined and concentrated in the separate thickening tanks provided. By proper control of the sludge volumes admitted and the solids detention in the thickeners, sludge concentration averaged 11.2 per cent solids for the year 1952. Sludge pumpage to the digesters was reduced to approximately one-third of the former volume (4).

During the first months of practicing this new method of sludge thickening, considerable attention was devoted to solving the control problems presented and the various mechanical difficulties encountered in pumping this viscous sludge. While these problems were being resolved, the digester operation remained unchanged; that is, two primary and two secondary digestion tanks were used.

It was found that gas production was becoming somewhat uneven during these first months. Investigation disclosed that sludge removed from the bottom of the primary digesters was cold and dense, resembling the raw sludge addition. It was evident that the sludge feed was settling to the bottom of the digester, mainly because it was considerably denser than the digester contents. A program of recirculating the primary digesters was initiated to overcome this sludge segregation. Suction was taken at the bottom of the digester being fed, the pumps discharging into the raw sludge feed line. As a result of this procedure, the accumulation of raw sludge at the base of the primary digesters was largely prevented and the gas production thereafter became more uniform.

At the beginning of 1952, the total volume of raw sludge added to the digesters averaged only 4,000 cu. ft. per day as a result of the raw sludge thickening process. The over-all digester displacement period had been increased to 180 days, as compared with an average of 54 days during the previous year. Since now there was 45 days displacement time available in each digestion tank, the possibility of

handling the entire plant load in a single digester presented itself. The low volume of raw sludge resulting from the new thickening procedure eliminated the need for using secondary digestion to decrease sludge volume. The question remained as to whether one digester loaded at about 7 lb. of solids per cubic foot per month and providing 0.5 cu. ft. of volume per capita would perform satisfactorily. Would one digester, having one-quarter the volume previously considered necessary, be able to destroy a normal percentage of organic matter, produce a gas of normal quality and quantity, and remain biologically stable? To determine whether such operation was feasible, it was decided to try adding all the raw sludge pumpage to a single digester.

One-Digester Operation

The trial operation started February 27, 1952, in digester No. 4, which had previously been used as a secondary tank and whose contents had been heated up to 95° F. It was hoped that the higher gas evolution would serve to circulate the digester contents and that recirculation by pump would not be required. Gas production was markedly low at first, increasing somewhat with time; but after 16 days of this high loading, violent foaming occurred at the gas holder seals. Samples withdrawn from the bottom of digester No. 4 contained cold, raw sludge. The operation was deemed unmanageable and the raw sludge was thereafter fed to two other digesters.

After resting the tank for almost one month, single-digester operation was resumed on April 10. On this occasion all four plunger pumps were used to provide continuous recirculation, with their combined flow discharging into the raw sludge feed line. Similar uncontrollable foaming occurred eight days after starting, the volatile acids concentration having increased to more than 2,000 p.p.m. Apparently recirculation had only hastened the onset of these undesired conditions. The sludge load was thereupon shifted to other digesters.

It was then reasoned that the upset might have been the result of the inability of those bacteria responsible for the decomposition of the organic solids to increase in number as rapidly as fresh food was being supplied. Based on this assumption, a final attempt was made to use a single digester by gradually increasing the proportion of the plant load fed to it. At first, digester No. 4 was fed every fourth day during a 12-day period. The load was then increased by feeding the digester on alternate days for six days. Two-thirds of the load was then applied by feeding No. 4 two out of three days for an additional 6-day period. On May 21, with satisfactory conditions continuing in digester No. 4 and the volatile acid concentration remaining at about 700 p.p.m., the full load was applied. This plant load, averaging 6.2 lb. of solids per cubic foot per month, was added to the single digester throughout the year. All during this period some digester recirculation was practiced, a total of 300 g.p.m. of digester contents being withdrawn from the decant and digested sludge levels and discharged into the raw sludge header to mix with the raw sludge feed. Thereafter, temperature readings of the sludge withdrawn from the supernatant and digested sludge levels were about the same, indicating that at least in the vicinity of those drawoff pipes pump recirculation was preventing any gross accumulation of cold raw sludge. During the course of this operation, the daily digester temperature varied slowly from a high of 99° F. in June to a low of 89° F. in September; for the remainder of 1952 the temperature ranged between 90° and 94° F. For a short period in January, 1953, the temperature of the digester fell to 85° F.

High-Rate Digestion of Combined Primary and Modified Aeration Sludge

From May 21, 1952, through January, 1953, the high-rate digester received all the plant sludge, which on a monthly basis averaged 5,000 to 6,800 cu. ft. per day. The corresponding liquid displacement periods were 36 and 26 days. As shown in Table I, the average solids concentration of the sludge added to the digester varied from 8.3 to 11.6 per cent, while the volatile content of the dry solids fluctuated between 65.1 and 79.9 per cent. The solids loading rate varied from 5.9 to 7.2 lb. per cubic foot of digester volume per month. Grab samples of thickened raw sludge were taken each weekday morning, centrifuged, and analysis made on the clear liquor for volatile acids, pH, and alkalinity. All volatile acid determinations included in this paper were made in accord with the procedure outlined in "Standard Methods." The distillations were made in a standard taper joint, all-glass still. The alkalinity of the liquor includes about 150 p.p.m. originally present in the raw sewage.

The results of the high-rate digestion are shown in the form of monthly averages in Table II. The concentration of digested sludge withdrawn from the supernatant drawoffs was found to average between 3.9 and 6.8 per cent solids, while the volatile content of the solids ranged from 61.0 to 48.0 per cent. In order to estimate the quantity of volatile matter converted to gas, an average was taken of the results from two methods of computing the pounds of volatile matter destroyed; namely, (a) by assuming constant ash and (b) by subtracting the volatile matter removed from the digester from the amount of volatile solids fed in the raw sludge. The values computed using these two methods were in reasonably good agreement, and their average was recorded in Table II. By dividing the amount of volatiles destroyed by the volatile input, the percentage volatile destruction has been calculated. This varies from 54 per cent for those months when sludge of the lowest volatile content was fed to 66 per cent when the raw solids contained a higher proportion of volatile matter. There appears to be the usual degree of volatile destruction, which fluctuates directly with the variations of volatile matter in the raw feed, as reported by Rankin (1).

In general, gas production from the high-rate digester was quantitatively similar to the amount generated in previous years when four digesters were used while the plant was employing the modified aeration treatment process. Likewise, gas quality, as measured by the CO_2 content of 34 per cent, was almost identical with that produced in previous years. Gas produced averaged 10.6 cu. ft. per pound of volatile matter added and 17.5 cu. ft. per pound of volatile solids destroyed for the period June, 1952, to January, 1953. The calculated results for the month of May have not been included in these averages because the period was short and influenced by previous operation. Included in Table II is the daily gas production per cubic foot of digester volume. This value, which can be readily determined for most digestion systems, can serve as a relatively accurate measure of the applied solids load per unit volume of digester. In many cases, sampling of sludge from primary settling tanks is notoriously poor. As a result, the reported values of unit digester loading are inflated. From Table II it can be seen that the high-rate digester produced an average of 1.7 cu. ft. of gas per day per cubic foot of digester capacity at a loading of 6.2 lb. per month per cubic foot, or 0.27 cu. ft. of gas per day for each pound per month of load per cubic foot of digester.

An attempt was made to evaluate the effect of temperature variation on the digestion process. It was hoped that

TABLE I.—Loading of Digester with Thickened Combined Primary and Modified Aeration Sludge

Month (1952)	Raw Sludge							Loading Rate				Dig. Temp.
	Pumpage	Displ. Period	Dry Solids (%)		Vol. Acids	pH	Liquor Alk.	Dry Solids (1,000 lb./day)		Unit Loading (lb./mo./cu. ft.)		
	(cu. ft./day)	(days)	Tot.	Vol.	(p.p.m.)		(p.p.m.)	Tot.	Vol.	Tot.	Vol.	(° F.)
May[1]	4,600	39	10.5	69.8	—	—	—	31.4	21.9	5.2	3.7	97
June	5,800	31	10.5	70.4	—	—	—	39.6	27.9	6.6	4.7	97
July	5,500	32	11.6	67.1	1,660	5.4	1,080	41.5	27.8	6.9	4.6	99
August	5,000	36	10.9	65.1	1,480	5.6	980	35.4	23.0	5.9	3.8	94
Sept.	5,500	33	10.2	74.2	1,230	5.4	740	36.4	27.0	6.1	4.5	90
Oct.	5,600	32	10.1	79.9	1,190	5.3	580	36.7	29.3	6.1	4.9	92
Nov.	6,300	29	9.5	79.2	1,130	5.5	750	38.9	30.8	6.5	5.1	92
Dec.	6,600	27	10.1	79.3	1,010	5.7	740	43.4	34.4	7.2	5.7	91
Jan.[2]	6,800	26	8.3	78.6	1,540	5.5	1,040	36.4	28.6	6.1	4.8	88
Av.	5,800	31	10.2	74.1	1,320	5.5	840	37.3	29.4	6.2	4.9	93

[1] May 21–31, inclusive. [2] 1953.

TABLE II.—Results of High-Rate Digestion of Thickened Combined Primary and Modified Aeration Sludge

Month (1952)	Digested Sludge Characteristics						Net Rate of Liq. Alk. Prod.	Vol. Matter Destr.[1]	Vol. Matter Destr.	Digestion Index	Gas Produced in High-Rate Digester						Gas Lost[2]
	Dry Solids		pH	Temp.	Digester Liquor						Vol. Prod.	Prop. of Tot. Avail.	CO_2 Cont.	Unit Gas Generation			
	Tot.	Vol.			Vol. Acids	Alk.								Per Lb. Vol. Matter		Per Unit Dig. Vol.	
	(%)	(%)		(° F.)	(p.p.m.)	(p.p.m.)	(lb./day	(1,000 lb./day)	(%)	(%/day)	(1,000 cu. ft./day)	(%)	(%)	Added (cu. ft.)	Destr. (cu. ft.)	(cu. ft./ day)	(1,000 cu. ft./day)
May[3]	5.5	54.8	—	97	700	7,700	—	—	—	—	252	—	—	—	—	—	—
June	6.3	51.0	7.6	97	570	6,900	2,140	15.9	57	38	258	92	33	9.3	16.2	1.4	22
July	6.6	49.4	7.5	99	540	6,700	2,220	14.4	54	40	286	93	34	10.3	19.9	1.6	22
August	6.8	48.0	7.4	94	420	7,000	2,000	12.5	54	40	245	94	34	10.7	19.6	1.4	17
Sept.	5.9	52.1	7.3	90	380	6,100	1,950	17.8	66	42	303	93	34	11.2	17.0	1.7	22
Oct.	4.9	59.4	7.2	92	500	5,600	1,860	19.2	66	43	356	93	34	12.2	18.5	2.0	26
Nov.	4.8	61.0	7.2	92	500	5,700	1,990	18.7	61	44	341	93	34	11.1	18.2	1.9	27
Dec.	4.4	60.3	7.2	91	410	5,900	2,540	22.4	65	51	322	93	35	9.4	14.4	1.8	23
Jan.[4]	3.9	59.6	7.2	88	380	5,600	1,800	18.6	65	47	296	92	35	10.4	15.9	1.6	24
Av.	5.5	55.1	—	93	470	6,200	2,060	17.4	61	43	299	93	34	10.6	17.5	1.7	23

[1] Volatile destroyed per day estimated by averaging the amount calculated after assuming constant ash and that calculated by the difference between the volatile matter input and output.

[2] Gas lost equals gas generated in digester No. 3. Gas utilized by engine measured by orifice-type meter, with base conditions of 84° F., 0.85 sp. gr., 3-in. water pressure. Gas generated by digester No. 3 measured by displacement meter.

[3] May 21–31, inclusive. [4] 1953.

operating over a range of from 80° to 100° F. would establish whether the high-rate digester was sensitive to temperature variations. Also it was intended that data be accumulated to test whether at some particular temperature in the mesophylic range the velocity of digestion could be increased, thereby minimizing the loss of gas by the high-rate unit. Unfortunately, because of the limited capacity of the digester heating system, only the temperature range of 85° to 99° F., on a daily basis, could be explored, since it was not considered safe to drop the temperature too low. There was little effect upon over-all digester performance between the temperatures used, possibly because of the masking influences of other factors.

The volume of digested sludge withdrawn from the high-rate digester was the same as that of the raw sludge feed shown in Table I. It is interesting to compare this volume of digested sludge withdrawn with the volume previously produced after digestion of the primary and modified aeration sludges using all four digesters in two-stage operation. The comparison is made on the basis of solids concentration, which varies inversely with the sludge volume. It has been demonstrated (2) that sludge concentration bears a definite relationship to the volatile content of the sludge. Figure 2 shows this relationship for the modified aeration process, comparing conventional digestion during 1950 and 1951, as shown in the above reference, with the 1952 plant operation. Over a volatile content range of 48.0 to 61.0 per cent, the 1952 data coincide so closely to the curve representing 1950–1951 operation that the results may well be indicated by a single line. Thus, the use of the more efficient thickening procedure followed by digestion in a single high-rate digester resulted in a digested sludge volume equal to that produced when conventional sludge pumping was practiced in conjunction wtih the use of all four digesters.

After May 10, 1952, digesters No. 1 and No. 2, which had been receiving a portion of the thickened combined sludge, did not receive any further addition. An opportunity was thereby presented to collect data relating to the time required, under ideal quiescent conditions, for the release of supernatant liquor. Samples of the contents

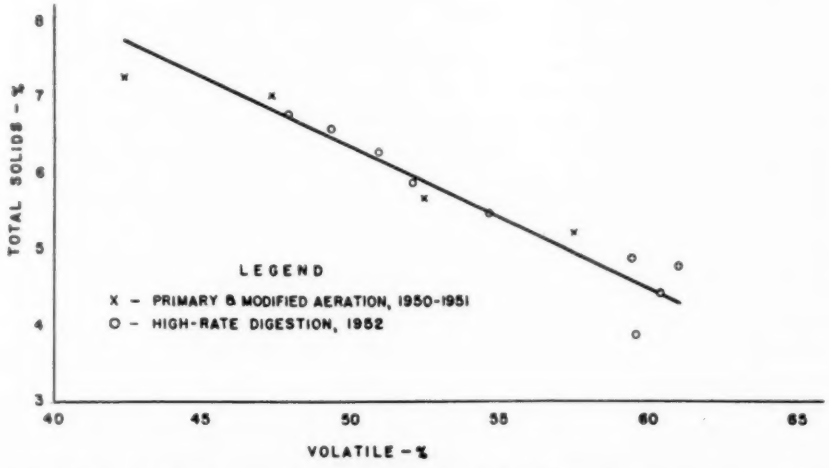


FIGURE 2.—Relation of concentration of digested sludge to volatile content; primary and modified aeration sludge.

of these digesters were taken periodically from the bottom of the digester and from the 27-ft. elevation supernatant drawoff level. The solids concentrations are plotted in Figure 3. Here it can be shown that, after a delay of one month, there was a gradual increase in the concentration of the digested sludge from about 5.4 to 8.5 per cent. At the same time, the solids content of the supernatant layer decreased to about 1.4 per cent after 70 days. Between 70 days and 110 days there did not appear to be any further significant change. Both tanks' performances appeared reasonably similar. From the data, it appears that if surplus digesters are available, some advantage may be taken of the long-term destruction of volatile matter and consequent increase in solids concentration. Re-treatment of the poor quality supernatant formed might be practiced if acceptable to the particular plant treatment conditions. However, it must be pointed out that storage of less than 70 days would have been ineffective from a sludge volume reduction standpoint, since little, if any, supernatant liquor would have been released.

In order to measure the amount of gas lost by using the single high-rate digester, sludge withdrawn through the supernatant drawoffs was passed to a second unit, and there held for an equal detention period. Although this second unit, digester No. 3, was not heated, its temperature was only 2° to 4° F. below that of the high-rate digester. This method of operation was started in June and continued through January. It was discovered that some of the gas produced by digester No. 3 had escaped under the lip of the gas holder when liquid levels were low for short periods in July and August. The records of gas production from digester No. 3 for these periods have been omitted from the results in Table II. In general, about 93 per cent of the normally available gas was produced in the high-rate digester. Operation of the high-rate digester by itself would thus have been responsible for a gas loss of only 7 per cent.

This gas loss was the necessary result of withdrawing sludge from the tank to provide room for the incoming raw sludge feed. Consider the theoretical case of a digester receiving a

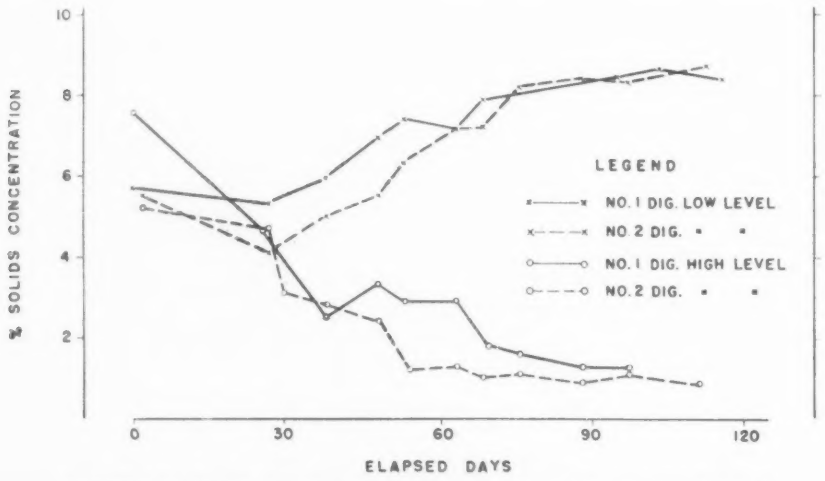


FIGURE 3.—Effect of time of storage on digested sludge concentration and supernatant formation.

continuous uniform feed and transferring sludge to a second digester. The first digester would be thoroughly mixed, so that the sludge transferred from it would be representative of its contents. Let Q equal the pumpage, V the volume of the first digester, G its daily gas production, and g the gas production of the second digester. Assuming equilibrium, g is equal to the gas remaining in volume Q of the transfer sludge, except for the gas lost in the sludge leaving the second digester. The available gas present in each unit volume of transfer sludge is g/Q. Since the transfer sludge is representative of the contents of the first or active digester, the total potential gas available in that tank would equal $V\ g/Q$. This quantity will vary with the rate of digestion, because a low rate will result in an accumulation of digestible material. Thus, there may be used, as an index of the efficiency and velocity of digestion, the daily gas production of the active digester divided by the gas available in its contents, or:

$$\text{Digestion index (\%/day)} = \frac{G\,Q}{g\,V} \times 100.$$

For the period June through January, the digestion index varied from 38 to 51 per cent per day, averaging 43 per cent, signifying that of the gasifiable material accumulated in the high-rate digester, 43 per cent per day was being converted. It is likely that the true value of the digestion index might have been much higher if it were not for the fact that a large volume of the digester was lost to uncirculated scum, together with inactive zones where heavier inert sludge and silt had accumulated. Efficient internal digester circulation for effective distribution of the raw feed to all portions of the tank after premixing the raw sludge with the digester liquor may be expected to increase the digestion index. As the index increases the gas loss decreases.

It can be seen from the data presented that for a period of more than eight months, one digestion tank received a solids loading that previously required four tanks. Operation was quite satisfactory at 0.5 cu. ft. of digester volume per capita, since 93 per cent of the destructible organic matter was converted to gas and the volume of digested sludge to be handled was essentially the same as that resulting from digestion in a 2.1-cu. ft. per capita system.

As shown in Figure 3, a possibility exists of reducing sludge volume by long quiescent storage of the digested sludge. This would require the use of all four digesters, one for use as the active unit and three for quiescent storage. Because of the low volume of sludge added to the digesters, the possible decrease in volume would be correspondingly small. In this case, it would require some 540,000 cu. ft. of digester capacity to achieve decreases in sludge volume of about 2,500 cu. ft. per day. It would be uneconomical to provide this digester volume to accomplish such small savings.

The stability of the high-rate digester, as demonstrated by the high pH and alkalinity, together with the low volatile acids concentration, points toward the likelihood of significant increases in digester loading. The loading averaged 5.9 to 7.2 lb. of dry solids per cubic foot per month at a digester displacement period of 31 days. Unfortunately, it was impossible to increase solids loading above that shown, since the digester volume could neither be decreased, nor could the raw solids feed be increased above that quantity captured by the treatment process. It was evident that a pilot-plant study would be necessary to aid in defining the upper limits of digester loading capacity and this project was initiated in 1953.

Interim Period

During the latter part of 1952 it was found that the raw sludge discharge

line to the digesters was becoming progressively clogged, with accompanying increases in discharge pressure. In January, 1953, a complete stoppage occurred and, while the line was being cleared, modified aeration solids were necessarily wasted to the primary settling tanks. For a week, mixed sludge was pumped from the primary settling tanks at more than double the former volume, as compared to the thickening of combined sludges in the separate thickening tank. As a result, the January data shown in Tables I and II are not entirely representative of the operation on thickened combined primary and modified aeration sludge.

In February, repeated interruptions to the thickener operation occurred mainly because of clogging of the raw sludge discharge line to the digester. Each time the modified aeration sludge had to be wasted to the primary settling tanks and the mixture of primary and modified aeration sludges was pumped to the digesters. Again, the raw sludge became very dilute, the volume almost tripling above that produced when using the new method of thickening. Digester alkalinity decreased from 5,200 p.p.m. in the beginning of February to 3,400 p.p.m. on March 4. The pH fell from a value of 7.2 to 6.8. The load on the high-rate digester was therefore reduced by feeding one-third of the plant load to digester No. 3 and such operation was continued for 12 days until March 16. Thus, it has been demonstrated that undue increases in sludge pumpage lowered the pH of this highly loaded digester, and, if continued, the process might be adversely affected.

High-Rate Digestion of Thickened Combined Primary and Activated Sludge

During the first half of March, secondary treatment at the plant was changed from modified aeration to the step aeration activated sludge process. After sufficient activated sludge culture had been accumulated, wasting of activated sludge began and thickening of combined primary and activated sludge commenced. Starting March 17, all thickened combined sludge was added to the high-rate digester.

At that time there became available a centrifugal pump having a capacity of 600 g.p.m., which could be used to increase the rate of digester recirculation. It was understood that the seal water required for the pump would dilute the digester contents, so the water was passed through a meter and limited to about 2 per cent of the volume of sludge entering the digester. Unlimited seal-water additions would defeat the basic objective of sludge thickening.

The results of thickening combined primary and activated sludge differ from those obtained with combined primary and modified aeration sludges. Although more solids were captured from the sewage by the activated sludge process, the concentration of the combined thickened sludge was considerably lower than for modified aeration and the volume was as much as 2½ times as large. The over-all effect on the high-rate digester was a small increase in solids loading and a relatively large decrease in the liquid displacement period. These quantities and rates of loading are shown in Table III for the months of March to August, 1953.

Sludge volume averaged from 6,800 cu. ft. per day in the latter part of March to 15,900 cu. ft. per day during July. The corresponding displacement periods were 27 and 11 days. Solids loading varied from 6.6 to 7.8 lb. per cubic foot of digester capacity per month. Digester temperature ranged from a high of 99° F. in March to a low of 90° F. in May. Solids concentration of the raw sludge feed varied from 9.0 to 4.6 per cent total solids having a volatile content of 69.4 to 75.7 per cent.

TABLE III.—Loading of Digester with Thickened Combined Primary and Activated Sludge

Month (1953)	Raw Sludge							Loading Rate				Dig. Temp.
	Pumpage	Displ. Period	Dry Solids (%)		Vol. Acids	pH	Liquor Alk.	Dry Solids (1,000 lb./day)		Unit Loading (lb./mo./cu. ft.)		
	(cu. ft./day)	(days)	Tot.	Vol.	(p.p.m.)		(p.p.m.)	Tot.	Vol.	Tot.	Vol.	(° F.)
March[1]	6,800	27	9.0	71.6	1,130	5.9	1,170	39.5	28.3	6.6	4.7	99
April	8,300	22	7.5	72.3	1,430	5.8	970	39.8	28.8	6.6	4.8	94
May	12,000	15	6.1	69.4	2,500	5.8	1,450	46.8	32.5	7.8	5.4	90
June	12,600	14	5.7	75.7	2,160	5.6	1,210	46.0	34.8	7.7	5.8	91
July	15,900	11	4.6	71.1	1,550	5.6	870	46.8	33.3	7.8	5.6	92
August	14,300	13	4.6	71.2	1,800	5.6	1,030	42.0	29.9	7.0	5.0	93
Av.	12,100	15	6.0	71.9	1,820	5.7	1,110	43.8	31.6	7.3	5.3	93

[1] March 17–31, inclusive.

TABLE IV.—Results of High-Rate Digestion of Thickened Combined Primary and Activated Sludge

Month (1953)	Digested Sludge Characteristics						Net Rate of Liq. Alk. Prod.	Vol. Matter[1] Destr.	Vol. Matter Destr.	Digestion Index	Gas Produced in High-Rate Digester						Gas Lost (1,000 cu. ft./day)	
	Dry Solids		pH	Temp.	Digester Liquor						Vol. Prod.	Prop. of Tot. Avail.	CO_2 Cont.	Unit Gas Generation				
														Per lb. Vol. Matter		Per Unit Dig. Vol.		
	Tot.	Vol.			Vol. Acids	Alk.								Added	Destr.		Dig. No. 3[2]	Total[3]
	(%)	(%)		(° F.)	(p.p.m.)	(p.p.m.)	(lb./day)	(1,000 lb./day)	(%)	(%/day)	(1,000 cu. ft./day)	(%)	(%)	(cu. ft.)	(cu. ft.)	(cu. ft./day)		
March[4]	3.1	54.6	7.2	99	190	4,400	—	—	—	—	199	—	38	—	—	—	24	24
April	3.7	50.6	7.1	94	320	5,000	2,810	17.6	61	35	284	88	37	9.9	16.1	1.6	37	37
May	4.1	55.7	7.1	90	440	5,300	3,710	15.0	46	43	323	87	36	9.9	21.5	1.8	46	50
June	3.6	61.7	7.0	91	400	4,700	3,340	16.4	47	36	347	84	36	10.0	21.2	1.9	61	68
July	3.0	61.4	7.0	92	290	3,400	2,990	14.6	44	42	265	83	35	8.0	18.2	1.5	48	56
August	2.8	61.8	7.0	93	410	3,400	2,970	12.4	41	51	251	87	35	8.4	20.2	1.4	37	39
Av.	3.4	57.9	—	93	360	4,400	3,160	15.2	48	41	285	86	36	9.2	19.4	1.6	44	48

[1] Volatile destroyed per day estimated by averaging the amount calculated after assuming constant ash and that calculated by the difference between the volatile matter input and output.

[2] Gas lost equals gas generated in digester No. 3. Gas utilized by engine measured by orifice-type meter, with base conditions of 84° F., 0.85 sp. gr., 3-in. water pressure. Gas generated by digester No. 3 measured by displacement meter.

[3] Total gas lost equals gas measured by No. 3 digester plus the calculated amount that would have been generated if the over-all detention time was 45 days.

[4] March 17–31, inclusive.

The results of this operation with thickened combined primary and activated sludges at these higher loading rates and short displacement periods are shown in Table IV. The March data, although included in the table, were influenced by previous operation of the digesters and so calculations based on this data were omitted. Since March represents a period of transition the results have not been included in the following discussion.

For the months April through August, digested sludge varied from 4.1 to 2.8 per cent solids having a 50.6 to 61.8 per cent volatile content. These solids concentrations appear similar to those obtained with conventional two-stage digesters at plants employing the activated sludge process.

The degree of destruction of volatile matter was lower when digesting activated sludge than for the modified aeration sludge. Volatile matter destruction ranged from 41 to 61 per cent. These lower percentages are ascribed to a lower volatile content of the thickened combined raw sludge feed and the aerobic digestion accomplished by the full activated sludge process. The gas formed contained about 36 per cent CO_2, compared to 34 per cent for the 1952 operation. Although less gas was produced per pound of volatile matter added—namely, 9.2 cu. ft. per pound—the 19.4 cu. ft. of gas generated per pound of volatile matter destroyed is slightly higher than in 1952, when 17.5 cu. ft. were generated. The gas production per cubic foot of digester averaged 1.6 cu. ft. per day, which is slightly lower than the previous rate.

The high-rate digester, receiving thickened combined primary and activated sludge, exhibited excellent stability. During a period in July, however, sludge pumpage increased to 19,000 cu. ft. per day for 9 days, and the displacement time was reduced to 9.5 days. The alkalinity dropped from 4,000 to 2,700 p.p.m. and the pH was depressed to 6.9 for a couple of days. At no other time during the six months operation was the pH below 7.0. The sludge pumpage subsequently returned to 15,000 cu. ft. per day and the pH immediately rose to 7.0. The importance of a high alkalinity reserve in maintaining stable operation is obvious. Shown in Table IV is the average quantity of liquor alkalinity produced daily. This quantity equals the alkalinity withdrawn daily from the digester in the digested sludge liquor, all alkalinities being determined on the supernatant after centrifuging, less the amount added in an equal volume of raw sewage, due correction being made for over-all changes in concentration of the alkalinity of the digester contents for the period under consideration. The total liquor alkalinity produced during thickening and digestion was calculated in this manner. The concentration of alkalinity in the digester is approximately proportional to the daily alkalinity production, and inversely proportional to the sludge pumpage, for a given quantity and type of solids to be digested.

For activated sludge operation the total alkalinity production averaged 3,160 lb. per day. It was noticed that, with modified aeration, as shown in Table II, the total alkalinity produced averaged 2,060 lb. per day. Apparently, a much greater quantity of alkalinity had been formed by the digestion of activated sludge solids than for modified aeration solids, since the primary solids were similar in both cases. A major factor in the ability of the high-rate digester to tolerate large volumes of thickened combined primary and activated sludge without significant depression of the pH thus appears to be the greater alkalinity production to be derived from the digestion of activated sludge.

It is not possible to compare directly this with previous digester operation in 1947 and 1949 because of the stated inadequacy of the digestion system to

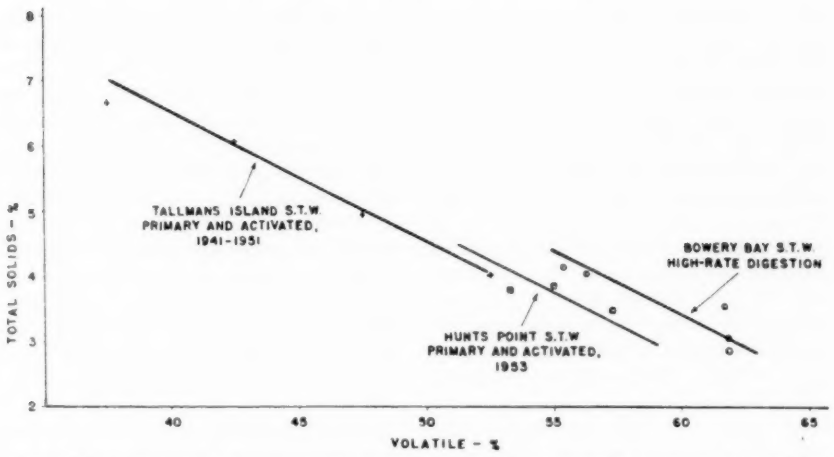


FIGURE 4.—Relation of concentration of digested sludge to volatile content; primary and activated sludge.

reduce sludge volumes when handling the conventional sludge pumpage, using two-stage digestion. In any event, all the primary and excess activated sludge solids from the combined thickening process were digested in one digestion tank, which was not accomplished by four digesters in 1949. Likewise during 1953, the volume of digested sludge to be disposed of was considerably less than in 1947, when all raw sludge entered the four digesters.

To compare this operation with that of digestion systems where primary and activated sludges are satisfactorily digested as well as concentrated, the relation of the solids concentration to solids volatile content of the digested sludge at the Tallmans Island (2) and Hunts Point plants was determined (Figure 4).

It can be seen that the Bowery Bay results fall slightly above those for the other two plants. Thus, it is apparent that the use of the combined thickening process and digestion in a high-rate unit with a capacity of 0.5 cu. ft. per capita produced a digested sludge whose concentration was essentially equal to that attained by digestion systems with capacities of 3.5 to 4.5 cu. ft. per capita. Again, as was shown with the modified aeration operation, the volume of digested sludge is the same whether produced by the combined thickening process followed by a high-rate digester or by conventional sludge pumpage plus an adequate two-stage digestion system.

As had been done previously, the sludge from the high-rate digester was transferred to digester No. 3, there to be held an equal displacement period to ascertain the quantity of gas being lost from the first unit. However, because of the low total displacement periods encountered, gas losses were corrected to an over-all digestion period of 45 days to compare with conventional digestion periods. Thus, during April, at a displacement period of 22 days, the high-rate digester lost 12 per cent of the gas available in 44 days, no correction being required. When the displacement period of that digester was reduced to 11 days, the calculated gas loss was 17 per cent. The digestion index averaged 41 per cent per day, which was slightly below the 1952 results.

These losses averaging 14 per cent

are economically significant where the gas is utilized for power generation. On the other hand, provision for extra digester volume to reduce these losses would require considerable capital outlays. A different method of solving this problem has been indicated by the results obtained from the parallel operation of a pilot digester.

By proper mixing of the contents of the pilot tank, gas losses have been reduced to one-third of those in the plant unit. Concurrently, the digestion index for the pilot digester has increased to more than 100 per cent per day at solids loadings even triple those of the plant unit. In this connection, the pilot plant was shown to be capable of producing more alkalinity when operating at the same loading. A greater percentage of alkalinity-producing solids, as well as gas-producing solids, was retained and converted by the pilot unit. Thus, it appears from observations of the pilot-plant operation that the high-rate digester, if provided with means for effective distribution of the feed to the entire volume, could handle triple the solids loading rate while maintaining the gas-producing efficiency.

Some Considerations in High-Rate Digestion

It has been demonstrated by extended operation at the Bowery Bay plant that it is possible to add sludge solids to a digestion system and obtain satisfactory results by normal standards at loading rates appreciably above those generally reported. Certain considerations apply to these high-rate digesters that are not important in conventional two-stage operation. Since the quantity of digested sludge is equal to that of the raw sludge, it is imperative that the sludge volume be reduced to a minimum, as has been accomplished by the combined thickening process. Any addition of water, such as for seal water for centrifugal pumps or for the flushing of Venturi meters, would increase the sludge volume, dilute the digester alkalinity, raise the gas loss, and therefore should be limited and, if possible, avoided.

At these higher solids loading rates, when higher bacterial densities are being maintained, it is important that the sludge feed be supplied almost continuously and at a comparatively uniform rate. If the food supply is interrupted for a significant period, the bacterial population is reduced and when feeding is resumed considerable time may be required to reestablish the population. Meanwhile, raw load and some intermediate products of digestion will accumulate, thus reducing process efficiency. When several thickening tanks are used to provide sludge for digestion in several tanks, a way of aiding towards attaining a uniform continuous flow of sludge to each digester would be to couple one thickener with one digester.

In connection with high-rate digesters, it has been found that some difficulty has been experienced in starting operation. As previously stated, bacterial density must be built up somewhat higher than in conventional units to accommodate the higher solids loading rate. When starting, therefore, it is imperative that the load be increased gradually over slightly longer periods than are generally required, until the entire plant load is applied. During this time, some provision must be made to dispose of the raw sludge not being digested. Similar considerations apply for plant shutdowns, when resuming high-rate sludge digestion.

At these higher digestion rates the entire volume of the digester should be utilized. Silt collections on the floor, scum accumulations, or poorly circulated zones can not be tolerated. Furthermore, the undigested solids must be distributed equally throughout the tank to obtain full benefit of the volume and prevent zones of lower activity. This can be accomplished by effective and continuous internal mixing of the entire digester contents. In addition, to prevent accumulation of

raw solids through segregation, the sludge feed should be thoroughly mixed with digester liquor prior to entering the tank. Seeding of the feed with the necessary organisms is thus accomplished, the raw sludge brought up to temperature, and digestion started immediately. If cold dense raw sludge enters a digester without pre-mixing, it may segregate out of reach of circulating devices. Where external sludge heaters are used, the heated digester contents should be discharged into the raw sludge header to mix with the raw sludge feed prior to entering the digester. Again, attention is directed to the necessity of avoiding the use of pumps requiring the addition of seal water to the sludge pumped.

There is no release of supernatant liquor when using the high-rate digestion process, since such excess water was removed prior to entering the digestion system. In larger conventional digester installations, the supernatant zone provides storage in the cycle of sludge disposal. Some provisons should therefore be made to store digested sludge as required by the particular plant.

The digestion process operated satisfactorily over a temprature range of 85° to 99° F. The heat requirements will be considerably reduced due to the smaller volumes of raw sludge entering the digester. With these high-rate digesters, having shorter displacement periods, temperatures may fluctuate more widely than in larger conventional systems, especially in the winter time. Proper controls should be provided for the heating system to minimize such variations.

Because of provisions for effective internal mixing of digester contents, the inlet and outlet piping arrangements are not critical, provided they are well separated with the sludge flow possibly baffled to prevent short-circuiting of raw solids from inlet to outlet. Gas takeoff arrangements should be large enough to handle the greater quantities produced in high-rate digestion. Gas storage by means of gas holders caused some minor difficulty at the Bowery Bay plant because of the accumulation of uncirculated, cold, greasy materials in the annular ring between the holder and the walls. The pilot digester operating in parallel with the large unit experienced no difficulty in this respect. Effective internal mixing of the greasy materials and their consequent digestion has prevented accumulation. In addition, the fixed cover of the pilot digester does not have any exposed annular ring and so the difficulty of circulating that zone was eliminated.

Summary

A high-rate digester, operating in the mesophilic range of temperature, has received the entire sludge load of the Bowery Bay plant, having a connected population of 350,000, for more than one year. By means of a newly developed process of thickening combined primary and excess secondary sludges, a relatively dense sludge was obtained, which was digested in a unit with a capacity of 0.5 cu. ft. per capita.

When the plant was using the modified aeration process of sewage treatment, the thickened combined sludge averaged more than 10 per cent solids having a normal volatile content. Digestion proceeded satisfactorily at a loading rate of 5.9 to 7.2 lb. per cubic foot per month and a displacement period of 31 days, showing marked stability and producing a gas of normal quality and quantity. Some 1.7 cu. ft. of gas per day was produced per cubic foot of digester volume. The volume of digested sludge was shown to be equal to that produced with conventional sludge pumping operation in conjunction with the use of two-stage digestion at 2.1 cu. ft. per capita.

Later, the step aeration activated sludge process was used for secondary treatment. The volume of thickened combined sludge increased, while the

solids concentration averaged 6 per cent. At a loading rate of 6.6 to 7.8 lb. per cubic foot per month, and an average displacement period of 15 days, digestion proceeded satisfactorily. Because of this higher rate of digester displacement, however, gas loss was increased to about 14 per cent of that available in a 45-day system, although some 1.6 cu. ft. of gas per day was being produced per cubic foot of digester capacity. The volume of digested sludge could not be directly compared to previous operation, since all four digesters were found to be inadequate to handle all the sludge load resulting from activated sludge treatment. Comparison was made, however, with two other activated sludge plants, equipped with digestion tanks having a capacity of about 4 cu. ft. per capita. Performance of the high-rate digester was equal to these systems of eight times the volume, on a per capita basis, with respect to concentration of digested sludge.

A pilot digester was operated at the same temperature and received the same thickened combined primary and activated sludge. With the aid of internal mixing, the pilot digester functioned efficiently at solids loading rates triple those in the plant digester, which is equivalent to digestion at 0.17 cu. ft. per capita.

Acknowledgments

Thanks are extended to Hubert Becker, Jr., in charge of the Bowery Bay plant, and his operating staff, who cooperated in the solution of the many problems confronted during this extended plant-scale investigation, and to A. H. Chasick and R. B. Wolf for their aid in the preparation and presentation of these data.

The author is especially grateful for the assistance and advice of Richard H. Gould, Director of the Division of Sewage Disposal, in carrying out and evaluating this work.

References

1. Rankin, R. S., "Digester Capacity Requirements." *Sewage Works Jour.*, **20**, 3, 478 (May, 1948).
2. Torpey, W. N., and Lang, M., "Elutriation as a Substitute for Secondary Digestion." THIS JOURNAL, **24**, 7, 813 (July, 1952).
3. "Standard Methods for the Examination of Water and Sewage." 9th Ed. Amer. Pub. Health Assn., New York, N. Y. (1946).
4. Torpey, W. N., "Concentration of Combined Primary and Activated Sludge in Separate Thickening Tanks." *Proc. Amer. Soc. Civil Eng.*, Separate (May, 1954).

DISCUSSION

By R. S. Rankin

Engineer, The Dorr Company, Stamford, Conn.

Every basic process used in sewage treatment at one time was carried out in batch operation. Now all are on a continuous basis with the exception of sludge digestion. Mr. Torpey and his associates have demonstrated on a plant scale that it is now possible to digest sludge on a continuous basis. Many previous obstacles to this accomplishment seem to have been overcome by a new approach to the problem resulting in a solution which should enable present and future plants to benefit.

Two different types of sludges have been digested on a continuous basis on a full-plant scale with significant savings in digester capacity requirements. The first series of tests on sludge produced in the modified aeration process showed that, with 0.5 cu. ft. per capita and a detention period of 31 days, substantially as satisfactory

end results were obtained as were formerly obtained when using 2.1 cu. ft. per capita and a detention period of 54 days. The significant difference is in the continuous feeding of a previously thickened sludge, in this instance to 10.2 per cent solids, compared to intermittent feeding of unthickened sludge. Other elements common to good digestion, such as temperature and pH, were unchanged from normal practice. Volatile matter reduction at the end of 31 days was 56.9 per cent, total solids reduction was 42 per cent, and gas recovery is estimated at 93 per cent of the total.

Thus, in this first series of tests, using only one-fourth of the capacity required for conventional practice they were able to produce a digested sludge of equal characteristics. Against this saving of three-fourths of the usual capacity requirements would have to be charged the cost of the thickening step. However, the capacity of the thickening tanks used in the tests amounted to not more than 0.25 cu. ft. per capita and as the type of tank used for thickening is no more costly per unit of volume than digesters, there is still an ample saving left.

The second series of tests were made using sludge produced in the straight activated sludge process. The volume requirements, although considerably more than with sludge from modified aeration, were nevertheless substantially below those of conventional methods. Again, continuous feeding of a pre-thickened sludge was the prime factor, with solids concentration averaging 6.0 per cent. The volume of daily feed allowed 15-day detention in the test digester, equivalent to 0.5 cu. ft. per capita. Volatile matter reduction at the end of 15 days was 45 per cent, total solids reduction was 32.5 per cent, and gas produced was 86 per cent of the total available. This compared with a requirement in 1949 of 2.1 cu. ft. per capita to treat 63 per cent of the daily sludge production. To treat satisfactorily 100 per cent of the sludge produced in 1949 would have required 3.4 cu. ft. per capita, with a resulting detention of 50 days.

Thus, in this second series, which was on straight activated sludge, it proved practical to operate with only about 15 per cent of the capacity required with conventional digestion methods. However, it might seem that the advantages of some increase in capacity would be justified to obtain a greater reduction in volatile matter, hence total solids reduction, and also consequent increased gas yield. Increasing the capacity sufficient to provide a detention of 30 days, for example, would result in a total volatile matter reduction of about 52 per cent and the total solids remaining would be about 62.5 per cent of the original solids, compared to 67.5 per cent with the 15-day detention. Whether this reduction justifies twice the digester capacity seems doubtful, but it is a question of economics to be studied for each plant.

The two series of tests prove that when pre-thickened sludge is fed continuously it is entirely practical to digest sludge in a tank with a capacity of not more than 25 per cent of that used in conventional plants. An essential requirement is that the plant has facilities for continous disposal of digested sludge.

A distinct advantage of the prethickening step is the elimination of the usual digester supernatant to return to the system and foul up the main treatment processes. With this method of operation the excess sludge liquor is removed ahead of digestion and, having characteristics essentially the same as raw sewage, its return to the system should have none of the harmful effects of digester supernatant. Moreover, the excess liquor is returned at a uniform rate and not in "slugs," which should result in definite improvement in the performance of primary clarifiers and subsequent biologic processes.

Probably one valid objection to this method of operation would be the inability in many plants of disposing of

the digester sludge continuously. Likewise, more plants comparatively use high-rate trickling filters than modified aeration and there is the obvious question of applicability. On the latter subject it is reasonable to assume that the behavior of sludge from high-rate trickling filter plants will be similar to that from modified aeration. Assuming this to be correct, the obvious solution to the problem of intermittent disposal is to provide storage capacity sufficient to take care of the intervals between sludge withdrawals. Using the unit capacity determined in the first series of tests, an additional 23 days of storage or a total of 54 days of detention can be provided with a capacity for the digester plus storage of only 0.9 cu. ft. per capita. This is still less than half of that required with current conventional methods. This additional 23-day storage is separate from the digester and can be in open or covered tanks depending on local conditions.

For an activated sludge plant it can probably be assumed that a period of around 50 days also will adequately bridge the interval between disposals. If this assumption is reasonable, a storage volume of 35 days capacity can be added. The total of digester plus storage volume in this case is 1.7 cu. ft. per capita, which is about 50 per cent of conventional requirements. Here, also, the storage volume is separate from the digester and can be in an open tank if desired.

One interesting observation in both series of tests is the relation between the solids concentration and volatile matter in the digested sludge. For the Bowery Bay sludge the maximum solids concentration depends on the volatile matter in the sludge, regardless of whether the sludge is thickened first and then digested, or digested first and then thickened. The first method seems to offer major advantages in reduction in size of digester and production of a supernatant having less harmful effects.

The cost of the digestion step in a sewage treatment plant is an appreciable percentage of the total. Costs will vary from about $0.80 per cubic foot for multiple units of large diameter, to $2.00 or $2.50 per cubic foot for the small units. In the large plants with continuous processing of digested sludge, savings with high-rate digestion should approximate up to $2.00 per capita, while in the smaller plants with intermittent disposal facilities, savings up to $3.00 per capita are entirely within reason.

One other economy resulting from Mr. Torpey's conclusions should not be overlooked. This is the saving in digester heating requirements. In raising the temperature of the pre-thickened raw sludge to that of the digester contents, the reduced volume makes quite a difference in heat requirements. Using the reported gas production during both series of tests, to raise the temperature of the digester feed 25° F. requires, for modified aeration, 4 per cent of the gas produced with high-rate digestion and 15 per cent of the gas produced with conventional digestion. With straight activated sludge the comparable values are 13 and 26 per cent, respectively. These savings do not include radiation losses, which will be considerably reduced with smaller digesters.

One problem which must be faced is obtaining approval of state agencies for reduction in their stated digester capacity requirements. Undoubtedly this will take time, but there is every reason to believe that when adequate data are available it will be sufficiently convincing, as it has been in the case of high-rate filters and, for that matter, many other improvements in the past years. With ever-mounting costs of sewage treatment, it is imperative that every means of reducing them for the hard-ridden taxpayer should be explored and utilized. It is hoped that Mr. Torpey's method of digestion will be one such means.

RADIUM AS A TRACER IN SEWAGE FLOW MEASUREMENTS *

By T. G. Bullen † and W. F. O'Connor ‡

Department of Public Works, County of Westchester, N. Y.

The relation of radium to radon and its products is shown in Table I, which gives the half-life of each step and the emission types. Radium A and its daughter products, all solids, contribute to the general activity of the radon, a gas of the inert group, if the latter is isolated from the parent radium and confined in an ionization chamber. Figure 1 shows the build-up of radon in contact with the parent radium. Figure 2 shows the decay of radon isolated from the parent radium. Figure 3 shows build-up of activity in an ionization chamber containing radon alone. Maximum activity is obtained after approximately 3.5 hr., at which stage an equilibrium of products has been reached. Thereafter, a slow decrease in activity is obtained, due to increasing loss of the radon, the most active agent producing the ionization. All measurements of radium were based on the ionization current produced by the maximum activity. If measurements were carried out before equilibrium was attained, an extrapolation factor was introduced to correct the experimental value to the equilibrium value.

The use of radium in flow measurements was first suggested by Groat (1) and has been successfully used by Hess (2). Archibald (3) has carried out flow tests using radioisotopes, but employed Geiger counter techniques instead of ionization chambers. The chief advantage of using radium as a tracer is that the radium in a sample may be estimated in terms of the radon produced in a given time. The extraction of radon can be carried out with ease in the presence of solids. The well-known difficulties of assaying radioisotope tracers in the presence of solids is thereby avoided. The work discussed herein has shown that radium is little affected by the presence of solids when the concentration is sufficient to give reasonable amounts of radon.

Apparatus and Technique

All measurements were based on the extraction of radon from radium-bearing solutions and the collection of the gas in ionization chambers, the radon

TABLE I.—Radium and Its Decay Products

Element	Atomic Wt.	Atomic No.	Half-Life	Particle Emitted
Radium	226	88	1,580 yr.	Alpha
Radon	222	86	91 hr.	Alpha
Radium A	218	84	3 min.	Alpha
Radium B	214	82	27 min.	Beta
Radium C	214	83	19 min.	Beta
Radium C′	214	84	10^{-4} sec.	Alpha
Lead	206	82	Stable	—

* Presented before Division of Water, Sewage and Sanitation Chemistry, at 122nd Meeting of the American Chemical Society; Atlantic City, N. J.; Sept., 1952.

† Present address: Iona College, New Rochelle, N. Y.

‡ Present address: Fordham University, New York, N. Y.

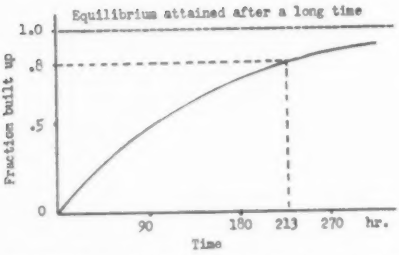


FIGURE 1.—Build-up of radon in contact with the parent radium.

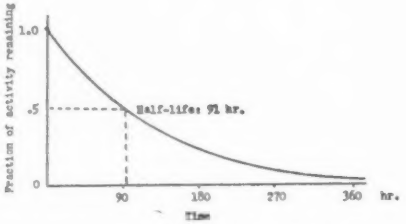


FIGURE 2.—Decay of radon isolated from the parent radium.

assay being carried out by means of a bi-filar electrometer. Figure 4 shows the ionization chamber, electrometer, and extraction apparatus.

The ionization chambers, of which several were used in rotation, were constructed of ⅛-in. wall brass pipe, 5½ in. in diameter and about 11 in. long. The neck, which fitted an entry on the electrometer, carried an amber plug, through which the central electrode projected. This allowed measurement of the ionization current in the chamber between walls and this electrode. The chambers were fitted with two stopcocks and a vacuum gage. To avoid errors in measurements due to variable electric field across the amber, all chambers were kept connected to a battery so that the field across the amber was constant, except when chambers were being transferred from reserve to the electrometer. Phosphorus pentoxide drying tubes were employed at all times to keep electrical leakage across the amber to a minimum.

The electrometer was a standard Wulf bi-filar instrument with a sensitivity of about 2.5 v. per scale division at 180 v. between fibers and the grounded case. Drying tubes were employed as shown, so that the ambers of both chamber and electrometer were protected against variable electrical leakage due to humidity changes.

The extraction apparatus consisted of three 1,000-ml. flasks arranged in cascade. It was found that three small flasks were more convenient than a single large one and were able to handle sufficient radium-bearing solution for accurate measurement. The aspirating tubes were fitted with porous stone spheres, which promoted adequate aeration of the solution with nitrogen,

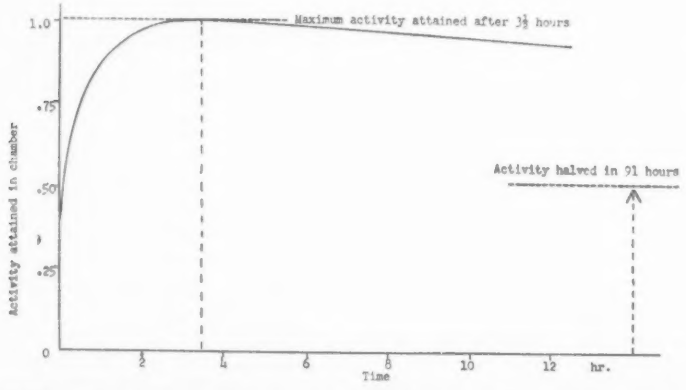


FIGURE 3.—Build-up of activity in an ionization chamber containing radon alone.

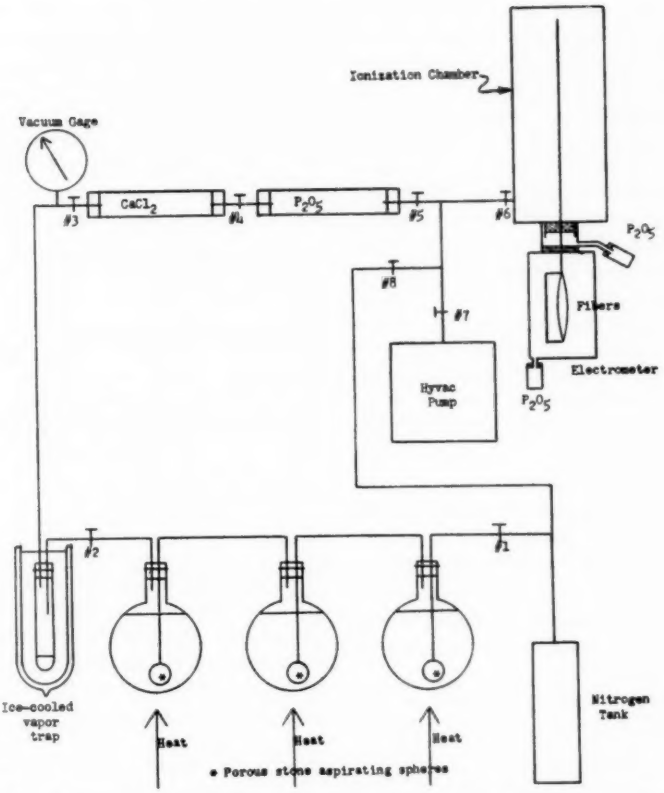


FIGURE 4.—Schematic diagram of aspirating system, ionization chamber and electrometer.

to effect complete extraction of the radon produced by the radium. The exit of the aspirating system led to a water vapor trap, a large test tube surrounded by ice, followed by a preliminary calcium chloride drying tube and then a phosphorus pentoxide drying tube. Stopcocks were placed as shown to isolate various parts of the system. The pentoxide and chloride were held in place in the tubes with fine steel wool. A vacuum gage and Hyvac pump completed the system.

Before making an extraction, it was necessary to determine the residual ionization current in the chamber to be used, before taking in the radon. This measurement is called the chamber background, and is due to residual radioactivity built up in the chamber during repeated use, cosmic rays, local gamma rays, and the amber leakage in the chamber and electrometer. Usually this corresponded to a movement of one scale division in 1,000 or more seconds, the chamber being filled to atmospheric pressure with nitrogen. Aged tank nitrogen was used, as the radon content of such nitrogen is insignificant after several days of storage.

The chamber was then connected to the aspirating system and was pumped out as far as stopcock No. 2, No. 8 being closed. In the meantime, a standard volume of 2,800 ml. of the radium-bearing sample was measured out. This was introduced into the three flasks and the stoppers were se-

cured. The tank nitrogen was connected at the left with stopcock No. 1 closed. The pumping was stopped when a pressure of about 0.1 mm. was obtained; stopcock No. 7 was then closed. On opening stopcock No. 2, the pressure above the solution in the flasks was sufficiently reduced to withdraw a large proportion of the radon and dissolved gases. By heating the flasks and by introducing nitrogen very slowly, it was possible to keep the solutions boiling under reduced pressure with a copious supply of nitrogen bubbles passing through. When atmospheric pressure had been attained in the ionization chamber, the aspiration was stopped, the whole process taking some 10 to 12 min. The chamber was usually allowed to stand for about 3½ hr. with stopcock No. 6 closed before making a determination of the equilibrium ionization current. The central electrode was kept at 180 v. negative with respect to the walls, for the reasons already noted.

The use of heat in aspirating was found necessary, as incomplete aspiration was found to occur if it was omitted. Repeated tests showed that aspiration was always complete when carried out as described.

Assay of the radon in the chamber was carried out by timing the movement of one of the electrometer fibers over ten scale divisions, a range of some 25 v. (190 − 165 v.), the mean of ten runs being taken when the time involved was reasonably short. The following is a calculation of a typical result:

Background count:
1,000 sec./scale div.
Radon count:
40 sec./10 scale div.
(4 sec./scale div.)
Electrometer sensitivity:
2.33 v./scale div.
Volume of solution used:
2,800 ml.

Since

$$Q = C\ V,$$

in which

Q is the total charge lost in time t,
C is the capacitance of the system, and
V is the voltage drop in time t,

and

$$\text{current} = Q/t,$$
$$\text{the ionization current} = C\ V/t.$$

Therefore,

Current due to background
$$= C\ 2.33/1{,}000,$$

Current due to background plus activity introduced $= C\ 2.33/4$,

and

Current due to the activity to be measured

$$= C\ 2.33\ (1/4 - 1/100).$$

From a calibration using a standard radium solution it was found that 1 g. of radium would give an equilibrium of radon equivalent to 1.68×10^8 v. per second. Therefore, 1 c. (curie) of radon would give an ionization current equal to $C \times 1.68 \times 10^8$. Hence, the concentration of radon in the solution is $\frac{C\ 2.33\ (1/4 - 1/1{,}000)}{C \times 1.68 \times 10^8}$ curies, where 1 c. of radon is equivalent to 1 g. of radium, when equilibrium is established. This gives a concentration of 3.462×10^{-9} c. of radon in 2,800 ml. of solution, or 1.238×10^{-12} c. of radon per ml. of sample.

It is worth noting that the background corresponds to only 5×10^{-15} c. per ml. of sample, and assuming that a 10 per cent change in counting time corresponds with the minimum detectable radon, the apparatus is capable of detecting 0.5×10^{-15} c. of radon per ml. of sample. This is considerably smaller than that found in some natural waters (Table II).

When making assays of radon to determine the amount of radium which has produced it, it is not necessary to wait for equilibrium to be established

between the radium and radon, which would involve at least 30 days. After 30 days, 99.8 per cent of the equilibrium is attained, assuming that the radium has been purged of all radon at the start of the period. Tables are available for determining the percentage of equilibrium attained after any known period of standing; these were employed to determine the extrapolation factor required to bring the observed result to equilibrium value that would have been obtained if the radon had been extracted after waiting for 30 days or more. Tables of results for actual tests show the appropriate factors actually employed in each determination.

Application to Flow Measurements

To estimate the amount of radium needed to make a dilution flow test on the two sewers selected for the purpose, it was necessary to determine what natural radioactivity was present in sewage, so that the added radium would give a suitable increase for accurate measurements. Samples of raw sewage were aspirated and the concentration of radon obtained was found to be considerably greater than that for natural waters in the vicinity.

This rather unexpected fact was utilized in an attempt to trace the ultimate fate of sewage at the outfalls of the New Rochelle and Mamaroneck treatment plants, as described in a subsequent paper. The activity was found to be due to dissolved radon alone, not to dissolve radium, the radon apparently being trapped in the soil interstices and brought into the sewers by infiltration. Its concentration varied with the weather conditions and the region through which the sewers passed. A partial study of this variation was carried out as a secondary project, the results being given in the subsequent paper cited.*

* Scheduled for publication in THIS JOURNAL, May, 1954.

TABLE II.—Natural Radioactivity of Water

Source	Dissolved Radium[1,2] (10^{-12} g./ml.)	Dissolved Radon[3] (10^{-12} c./ml.)
Water sup., Barcelona	190 to 480	—
Sea water, average	0.08	—
Spring water:		
Colorado	270,000	—
Japan	703,000	—
Germany	250	—
Saratoga	750	—
Water sup., New Rochelle, N. Y.	—	2.0
Pond water:		
New Rochelle H. S.	—	3.0
Iona Coll. campus	—	2.8
Long Island Sound, except at outfall	—	0.5 to 3.0
Raw sewage	—	30 to 120

[1] From Reference (4).

[2] 1 g. of radium produces 1 c. of radon when equilibrium has been attained.

[3] As determined with apparatus described in this paper.

The principle involved in the flow measurements requires that a tracer be injected into the sewer in solution form, at a known rate. Assuming thorough mixing, a condition readily achieved, it follows that the ratio of the injection rate, q, to the flow rate of the sewer, Q, is the ratio of the concentration of the samples withdrawn downstream to that of the injection solution. The volume of injection solution used is insignificant compared with the volume of sewage into which it flows. Mathematically expressed, the desired flow rate will be, for all practical purposes,

$$Q = q\ c/C$$

in which c and C are the concentrations of the injection solution and the sample, respectively.

Because of unsteady mixing of the injected solution for a brief period at the start of injection, and a similar effect when injection ceases, it is necessary to carry out injection for a sufficiently long period to establish a steady state of dilution. The results of the tests showed that this condition was reasonably satisfied. Thus, tailing of the injected solution was noticeable for only a small fraction of the injection period.

Two sewers were selected for these pilot tests, which were run in the summer of 1951. Both sewers feed into the South Yonkers sewage treatment plant, located close to the north New York City line on the east shore of the Hudson River. From the data available, flow rates were estimated at about 5 and 35 m.g.d., respectively, for average days. Approximate calculations showed that 1 mc. (millicurie) of radium, as radium bromide, would suffice for a preliminary test in each case. The time of injection was 20 min. for the 48-in. sewer and 15 min. for the 102-in. sewer.

A simple injection system (Figure 5) was constructed and tried out with water to test its suitability. A large glass bottle of some 14-l. capacity was fitted with a syphon tube and rubber bulb for initiating syphoning. The syphon tube was connected to a long rubber tube capable of reaching close to the sewage level from the manhole at road level, the lower end carrying a glass jet of suitable diameter, found by trial and error. The injection solution was prepared by making up 1 mc. of radium bromide solution to fill the bottle, the radon being aspirated from the solution just before use. In this way, the zero time for calculating the radon build-up in the samples was known, thus allowing radon assay to be made without holding the samples for at least 30 days.

Valentine Lane Sewer Test

Figure 6 shows the location of the Valentine Lane sewer with respect to the South Yonkers treatment plant. Injection was carried out at a manhole 1,060 ft. from the plant. The depth of the sewer at this point was 33 ft. below the road level. Planks were inserted in the sewer at a manhole about 680 ft. south of the injection point, where the depth is about 9 ft. to promote good mixing conditions. Sam-

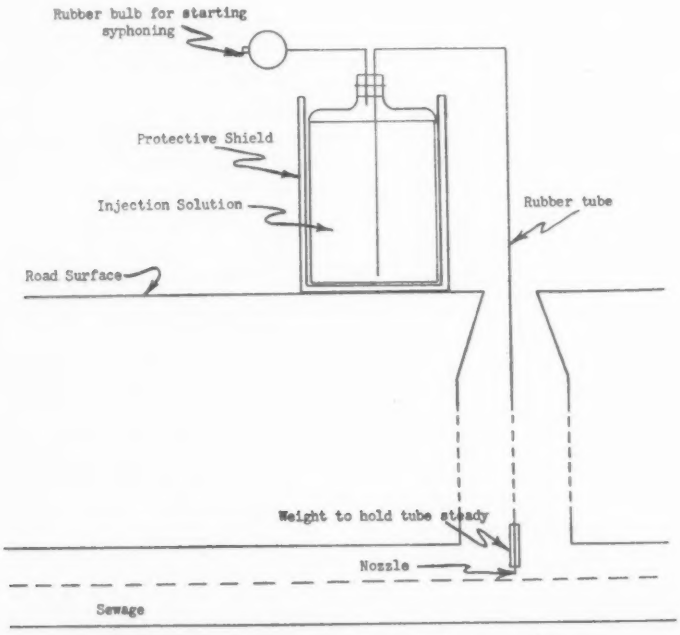


FIGURE 5.—Injection system for radium solution.

pling was carried out at the last manhole just outside the treatment plant.

Five gallons of raw sewage were first taken for background measurements and making up standard comparison solutions from the injection solution. The injection was then initiated, a small amount of fluorescein being injected at the same time to act as a marker. Sampling was started as soon as the fluorescein was seen at the sampling point; 1-gal. samples were taken at 1-min. intervals for 20 min., corresponding with the period of injection. A final sample was taken 5 min. after the sampling period expired, to check tailing of the injection solution. The samples were collected after straining out solids, in clean 1-gal. bottles, about 5 ml. of Clorox being added to each in an attempt to sterilize the sewage. The bottles were tightly stoppered with corks, metal screw caps being used over these to prevent leakage of radon.

The remainder of the injection solution, left in the injection bottle after syphoning ceased, was used to make up comparison standards of radium solution which would be of the same order of dilution as the samples taken in the test. The direct determination of the strength of the injection solution would have been impossible, because the excessive activity to be measured would have caused too rapid a movement of the electrometer fibers. The comparison standards were made up with raw sewage, taken just before the test commenced, as it was desirable that these standards should stand under the same conditions as the flow samples. The comparison standards were made by diluting the injection solution 100:1, 40 ml. of this being made up to 1 gal. with the sample. Three such comparison standards, 1/9,455th of the original strength of the injection solution, were prepared.

The summary of results for this test (Table III) shows that equilibrium was attained in the injection process

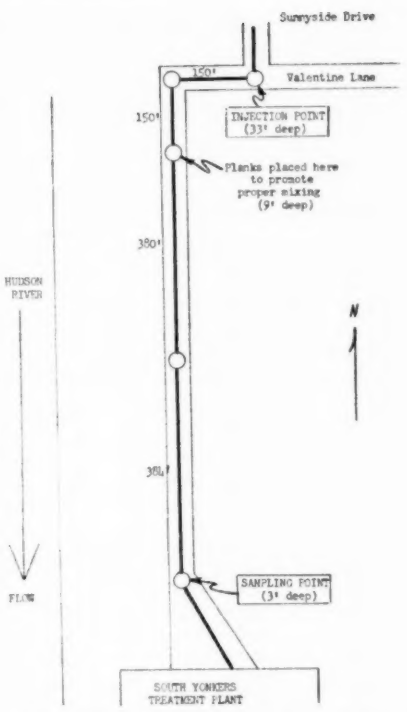


FIGURE 6.—Plan of Valentine Lane sewer, showing injection and sampling points.

for almost the whole period of sampling, the variations being attributed to the varying rate of flow of the sewage. Some samples were aspirated a second time after standing for a known period and the close agreement of the duplicated values illustrates the accuracy of the electrometer method in the assay of radium in terms of radon. Due to the high concentration of radon from the injected radium, it was found unnecessary to allow for the natural radon present in the sewage, as this decayed to negligible concentration during the standing period of the samples before assay. As the flow rate was calculated in terms of the ratio of concentrations of radon, it was unnecessary to employ the calibration factor of the electrometer and any error in this factor automatically cancelled out.

TABLE III.—Summary of Results for Valentine Lane Flow Test [1]

Sample No.	Date of Aspiration	Time of Radon Build-Up (days)	(hr.)	Equilibrium Attained (%)	Activity (10^{-5} c./ml.) Measured	Extrapol. to Equil.[2]	Flow Rate[2] (m.g.d.)
				(*a*) Comparison Standard Solutions			
1	9/5	7	2	72.3	3,979	5,500	—
2	9/6	8	3	77.1	4,210	5,460	—
3	9/7	9	3	80.7	4,360	5,380	—
1	9/19	14	3	92.3	5,020	5,440	—
2	9/20	14	5	92.4	5,050	5,470	—
				(*b*) Test Sample Solutions			
1	9/12	15	2	93.5	45	48	—
2	9/12	15	1	93.5	1,265	1,355	—
3	9/6	9	0	80.4	2,385	2,970	—
3	9/20	14	2	92.2	2,805	3,040	4.00[3]
4	9/7	10	0	83.7	2,617	3,122	3.84
5	9/5	8	1	76.7	2,220	2,763	—
5	9/19	14	3	92.3	2,540	2,758	4.35[3]
6	9/8	11	0	86.4	2,678	3,100	3.88
7	9/11	14	2	92.2	2,750	2,985	4.02
9[4]	9/11	14	2	92.2	2,741	2,979	4.03
10	9/5	8	1	76.7	2,205	2,879	—
10	9/19	14	3	92.3	2,618	2,840	4.19[3]
11	9/6	9	1	80.6	2,410	2,990	4.02
12	9/7	10	1	83.8	2,655	3,163	3.79
13	9/8	11	0	86.4	2,500	2,902	4.04
14	9/11	14	3	92.3	2,504	2,710	4.43
15	9/5	8	1	76.7	2,228	2,778	—
15	9/19	14	3	92.3	2,490	2,700	4.38[3]
16	9/20	14	5	92.4	2,505	2,710	4.43
17	9/7	10	1	83.8	2,303	2,750	4.36
18	9/8	11	1	86.5	2,195	2,541	4.92
19	9/8	11	2	86.6	2,010	2,322	5.16
20	9/12	15	1	93.5	2,590	2,772	4.33
21	9/12	15	0	93.4	98	105[5]	—

[1] Date of test, Aug. 30, 1951; injection rate, 10.22 ml. per sec.

[2] Average of extrapolated values from Nos. 3 to 17 inclusive is 2,888, giving a mean flow rate of 4.17 m.g.d.

[3] Mean of two determinations for same sample.

[4] Sample No. 8 spoiled.

[5] Tail sample 5 min. after injection ceased.

The values are quoted in curies per milliliter to indicate the levels of activity employed in the tests.

The flow rate in milliliters per second was found from

$$Q = q\ c/C$$

the value of c being found by determining the strength of the comparison standards and multiplying the values obtained by 9,455, the dilution factor. The value of Q was then converted to m.g.d. The mean value obtained falls within the values obtained by using a V-notch weir and by calculation from the level of sewage in the grit chambers of the treatment plant. It was unfortunate that a V-notch test could not be carried out simultaneously to make

a more satisfactory basis for comparison.

Bronx Valley Sewer Test

Attempts to gage the Bronx Valley sewer were of particular interest, as no direct flow measurements have ever been made, because of difficulties caused by a most unusual terrain in which the plant is located. Figure 7 shows the layout of this sewer with reference to the treatment plant. It passes through a 102-in. tunnel in solid rock for some 7,000 ft. and enters the plant through a steep wall of solid rock immediately outside the plant wall. Injection was carried out at the last manhole, close to the Saw Mill River Parkway, where the sewer is about 11 ft. below the ground. Sampling was done at the influent chamber just inside the plant. It was considered advisable to reduce the time of injection, owing to the much greater flow rate. This proved somewhat unfortunate, as the injection equilibrium was apparently attained for only 2 or 3 min. A much stronger radium solution would have proved more suitable, with an injection period of 30 to 40 min. In spite of this, the test was sufficient to illustrate the value of the technique employed. Comparison standards were prepared as in the Valentine Lane test, but with a dilution factor of 151,280. Owing to the lower concentration of radon from the flow samples, it was necessary to allow for the background of radon naturally present in the sewage. A further correction was incorporated for the slowing of the injection rate, due to the appreciable loss of head (about 4 per cent, which occurred during the injection of the radium solution. A blank test with water under identical conditions was carried out to determine the correction at 1-min. intervals.

Table IV gives a summary of the experimental data of this test. The average flow rate falls within the values obtained from sewage level measurements used in the past to estimate the flow. The tailing of the injection solution was also much more noticeable in this case, because of a much greater distance between the injection point and the sampling point. The spread of the fluorescein, used as a marker, confirmed this.

Comparison with Other Methods

Measurements of the same nature as those just described could be carried out using radioisotopes and Geiger techniques. Mechanical methods using Venturi and weir principles could also be used. It is felt that the method described has several advantages over these. The insertion of weirs is sometimes impossible due to high flow velocity and the large volume of sewage handled. Lack of space may prevent the installation of a Venturi chamber. Radioisotopes are liable to introduce many difficulties in counting techniques. Solids, fats, and greases interfere with dipping counters, whereas the presence of miscellaneous radioactive materials makes the determination of background uncertain. The concentration of tracer required for dipping counters would have to be much higher (3) to make measurements with reasonable accuracy, thus offsetting the relative cheapness of such tracers as radioiodine. The short half-life of common radioisotopes (Table V) is also

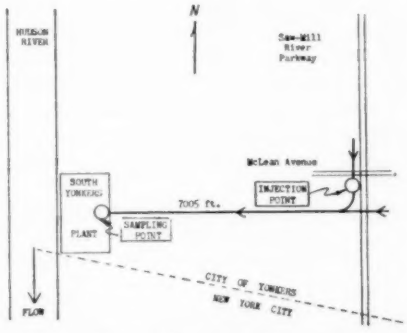


FIGURE 7.—Plan of Bronx Valley sewer, showing injection and sampling points.

TABLE IV.—Summary of Results for Bronx Valley Flow Test [1]

Sample No.	Date of Aspiration	Time of Radon Build-Up (days)	(hr.)	Equilibrium Attained (%)	Activity: Measured [2]	Activity: Extrapol. to Equil.	Flow Rate [3,4] (m.g.d.)
		(a) Comparison Standard Solutions					
A	9/25	7	5	72.9	274	375	—
B	9/26	8	6	77.6	289	372	—
C	9/27	9	6	81.3	305	375	—
		(b) Test Sample Solutions					
1	10/2	14	5	92.4	286	310	62.2
2	10/2	14	5	92.4	400	434	44.2
3	9/27	9	5	81.1	446	545	35.1
4	9/27	9	5	81.1	447	547	34.9
5	9/26	8	5	77.4	486	629	30.3
6	9/25	7	4	72.8	461	634	29.9
7	9/25	7	4	72.8	468	643	29.4
8	9/25	7	5	72.9	491	674	28.0
9	9/26	8	6	77.6	525	676	27.8
10	9/26	8	6	77.6	508	656	28.5
11	9/27	9	6	81.3	526	644	29.0
13	10/2	14	5	92.4	531	575	32.2
14	10/2	14	6	92.5	531	574	32.2
15	10/9	21	2	97.8	403	412	—
16	10/4	16	4	94.7	250	264	—
17	10/9	21	2	97.8	184	189	—
18	10/4	16	4	94.7	129	136	—
20	10/4	16	4	94.7	31	33 [5]	—

[1] Date of test, Sept. 18, 1951; mean injection rate, 14.78 ml. per sec.
[2] Corrected for natural background activity.
[3] Allowance made for the 4.5 per cent decrease in head of the injection solution throughout the injection period.
[4] Average flow rate calculated from Nos. 5 to 11 inclusive is 28.99 m.g.d.
[5] Tail sample 5 min. after injection ceased.

a disadvantage, involving troublesome corrections for the decay of samples under assay. With a Geiger counter method, the precipitation of the radioisotope by chemical means is decidedly unreliable at low concentrations and the counting of samples must be corrected for geometry, back-scattering, and absorption by foreign matter. The chief advantage of the present method lies in the fact that the radon to be assayed can be separated from all solids and interfering radioactive materials by a very simple and reliable means and an accurate count made at relatively low activities.

TABLE V.—Half-Lives of Some Radioisotopes Commonly Used as Tracers

Isotope	Half-Life	Relative Activity	Particle Emitted
Carbon 14	5,000 yr.	Low	Beta
Sodium 24	14.8 hr.	High	Beta, gamma
Phosphorus 32	14.3 da.	High	Beta
Iodine 131	8.0 da.	Medium	Beta, gamma
Radium 226	1,590 yr.	High	Alpha

The use of radium as a tracer in flow measurements appears to have many possible future applications. The cost of apparatus and tracer used in this work was approximately $750, comparing favorably with that required for radioisotope methods. The level of radioactivity in the sewer when treated with radium is very low in

comparison with natural activities listed in Table I, and does not approach anywhere near the danger level. Flow measurements in systems other than sewers could be carried out by applying the same technique. Tracing the ultimate fate of sewage discharged into coastal waters appears feasible.

Acknowledgments

Acknowledged with thanks is the encouragement of James C. Harding, Commissioner of Public Works, to undertake this program, as well as the assistance he provided throughout. Thanks also are due to Henry Miranda, who ran most of the determinations.

References

1. Groat, B. J., "Chemi-Hydrometry and its Application to Precise Testing of Hydro-Electric Generators." *Trans. Amer. Soc. Civil Eng.*, **80**, 951 (1916).
2. Hess, V. F., "On the Radioactive Tracer Method in the Measurement of Water." *Trans. Amer. Geophys. Union*, Part II, 587 (1943).
3. Archibald, R. S., "Radioactive Tracers in Flow Tests." *Jour. Boston Soc. Civil Eng.*, **37**, 49 (1950).
4. Love, S. K., "Natural Radioactivity of Water." *Ind. Eng. Chem.*, **43**, 1541 (1951).

NON-MEMBER MEETINGS OF INTEREST

The 1954 Southern Industrial Wastes Conference will be held at the Shamrock Hotel, Houston, Tex., April 21–23, 1954. The conference, expected to be the largest conference of its kind in the South, is jointly sponsored by the Southern Association of Science and Industry, the Texas Chemical Council, and the Manufacturing Chemists' Association.

A one-day conference on Instrumentation in Water, Sewage, and Industrial Waste Treatment, to be held April 20, 1954, at Manhattan College, New York, N. Y., is planned to bring together both makers and users of instruments for water purification and waste treatment. Additional information may be obtained from: Civil Engineering Dept., Manhattan College, New York 71, N. Y.

The Fourth Inter-American Conference of Sanitary Engineering, organized by the Inter-American Association of Sanitary Engineering, will be held July 25–31, 1954, at São Paulo, Brazil. Detailed information may be secured by contacting the General Secretariat, Fourth Inter-American Conference of Sanitary Engineering, Postal Box 8099, São Paulo, Brazil.

RESEARCH ON ACTIVATED SLUDGE—A DISCUSSION

By Henry R. King

Senior Civil Engineer, The Sanitary District of Chicago, Ill.

The oxygenation rates of water obtained by means of brush aeration as reported by Pasveer (1) are of particular interest, inasmuch as similar tests on diffused air aeration have been made by The Sanitary District of Chicago. Mr. Pasveer's statement that ". . . a value of 400 g. per hr. per cu. m. for the oxygenation capacity can thus be obtained, whereas in the aeration system used in practice this value is only 50 to 80 g. per hr. per cu. m. at the utmost . . ." needs clarification.

The brush as a device for oxygenation of water has a limited capacity. The high oxygenation values were obtained by reducing the volume of water per unit length of brush to such an extent as to be impractical for treatment plant application. Tanks of 2- to 3-ft. depth are not economical. Several of the measurements reported indicated that a brush oxygenation capacity as high as 800 g. per hr. per meter of length could be obtained. If it is assumed that brushes of such capacity could be installed so that their effective length would be 80 per cent of the aeration channel length, for 15-ft. deep tanks such as are in general use in large plants in the United States and for an oxygenation rate of 50 g. per hr. per cu. m., the brushes could supply aeration channels of only 9.2 ft. width; possibly as narrow as practical if adequate circulation is to be maintained. Therefore, for aeration tanks of 15-ft. depth it appears that the capacity of brush aeration is such as to satisfy moderate oxygen requirements rather than to produce unusually high rates of oxygenation.

If rates of oxygenation for activated sludge are ever required much higher than the general practice today, diffused air aeration probably offers the greatest possibilities in large plants. With diffused air, oxygenation capacities are unlimited. Also, the channels can be constructed of any width and depth that may be desired. Measurements made in the Sanitary District of the power required for diffused air aeration for oxygenation rates up to 110 g. per hr. per cu. m. indicated considerably higher oxygenation per kilowatt-hour of gross power (blower efficiency and piping and diffuser losses included) than were obtained in the brush aeration tests. Diffused air has no limitation as to oxygenation rate obtainable, except economic due to reduced efficiency as the rate increases. The Sanitary District tests, however, gave definite indications that rates of oxygenation by means of diffused air up to several times present day requirements can be obtained in any depth tank and at lower power, per unit of oxygen absorption, than that which Mr. Pasveer reports for brush aeration.

Reference

1. Pasveer, A., "Research on Activated Sludge. II. Experiments with Brush Aeration." This Journal, **26**, 12, 1397 (Dec., 1953).

Industrial Wastes

CLARIFICATION BY FLOTATION AND RE-USE OF LAUNDRY WASTE WATER*

By Herbert J. Wollner, Victor M. Kumin, and Peter A. Kahn

Respectively, President, Assistant Director of Research, and Research Engineer, American Conditioning House, Inc., Boston, Mass.

The study reported herein was sponsored by the Navy Department as a part of its program to see to it that advanced bases are adequately supplied with water for health and sanitation. A method has been developed for reducing by 87 per cent, and potentially up to 95 per cent, the fresh-water requirements for laundering where soap is employed as the principal detergent. The method is based on the flotation of flocculated chemical coagulants and has been applied on pilot plant equipment.

The primary objective of this research was to assure maintenance of high sanitation standards for military personnel at stations where natural water supplies are inadequate. The process which has been developed, however, is applicable not only to laundries, but also to other industrial wastewater problems where treatment for disposal or re-use is desirable.

The following figures indicate the magnitude of one of the Navy's water supply problems and provide a frame of reference for this discussion. Laundering requires 4 to 5 gal. of fresh water per pound of soiled fabric. For a 5,000-man base, 325,000 gal. of fresh water per week would be required for laundering, assuming 13 lb. of soiled articles per man per week. If the laundry for this installation operates 100 hr. per week, 3,250 g.p.h. of water would be required. In a fully occupied 1,000-bed hospital where 3,000 additional personnel are stationed, it has been estimated that 50 lb. of soiled articles must be laundered per bed per week in addition to 13 lb. per man in attendance. For a hospital of this size, therefore, 445,000 gal. of fresh water per week would be required for laundering. If the laundry for this hospital is operated 100 hr. per week, 4,450 g.p.h. of fresh water would be required. It is recognized that all advanced military installations must be prepared to maintain their own health and sanitation services, that they must be able to launder their own clothes and keep their hospitals supplied with clean linen. The research program reported here was undertaken with that in mind.

Historical Background

Laundry waste water in urban centers of America makes up 5 to 10 per cent of the average daily flow of sewage, but is 10 to 20 times as contaminated (1); it is one of the most objectionable of all wastes. It is generally alkaline; highly colored; contains large quantities of soap or synthetic detergents, soda ash, grease, dirt,

* Taken from a paper presented at Advanced Base Water Supply and Sanitation Symposium, sponsored by Bureau of Yards and Docks, Department of the Navy; Port Hueneme, Calif.; Oct. 7–9, 1953.

and dyes; and has a B.O.D. two to five times that of domestic sewage. Any attempt to clarify it must cope with these impurities.

Historically, many efforts have been made to treat laundry waste (2)(3)(4)(5)(6)(7). The chemicals used in these treatments included aluminum, iron, and calcium compounds, and silicates, separately or in combination.

Boyer (3) reported some success with chemical precipitation, but preferred trickling filters. McCarthy (7) reported treatments for disposal both by coagulation and settling and by trickling filters. Eliasson and Schulhoff (4) reported on a laboratory flotation device for clarification of laundry waste utilizing vacuum techniques to provide a source of bubbles for flotation, and lime, alum, and ferric chloride as coagulants. Newell *et al.* (6) reported on the removal of plutonium from laundry wastes by both chemical precipitation and trickling filter techniques. Early in 1953, the Florida State Board of Health (5) reported the use of a flotation process based on lime and sodium silicate as coagulants. But all these studies were for the purposes of disposal only, not to recover the water in a sufficiently pure state for re-use.

The treatment for disposal of waste water containing soap presents no serious complications. The soap can be converted to the free fatty acid, which can then be removed, or lime can be added to precipitate metallic soaps, which can then be separated. The effluent from such an operation is substantially free of suspended matter and apparently does not present serious difficulties in subsequent biological treatment (7). The treatment of waste waters containing synthetic detergents, however, is an entirely different matter. These compounds have found almost universal application where high dispersing power is required, particularly where hard waters are employed. Major uses have been in textile finishing, in domestic and commercial laundering, and particularly in laundering for military installations where only hard water is available.

The very properties which make these compounds so useful also make them troublesome when it comes to treatment of wastes containing them. Synthetic detergents can cause frothing, promote emulsification, and are even reported to have biological effects (8). They can stimulate slime growth in sewers and drains and can cause them to clog. Their dispersing power is so great that they can prevent adequate removal of solution contaminants by settling and consequently increase the load in subsequent biological treatment (9)(10)(11).

Ordinarily one uses synthetic detergents in concentrations of 100 to 1,500 p.p.m. to get the maximum effect desired, but it has been found (8)(10) that even 3 to 5 p.p.m. can inhibit floc formation with the usual coagulants and thus interfere with settling or flotation.

These problems are noted here because of their similarity to those that arise when one attempts to clarify for re-use waste water containing synthetic detergents. An investigation with that objective is currently in progress.

Procedure and Equipment

The technique used to treat laundry waste water for re-use is based on the flotation of flocculated coagulants which adsorb and entrain the suspended or colloidal soils. The use of flotation, *per se*, is not new. It has a long history of successful application in ore separation. Kalinske (12), D'Arcy (13), Gibbs (14)(15), Barry (16), and Easton (17) have reported a variety of applications of flotation equipment in the waste treatment field.

Early experiments have indicated that the type of chemical floc formed by coagulation in laundry waste water could best be separated by flotation. Equipment of this nature had been de-

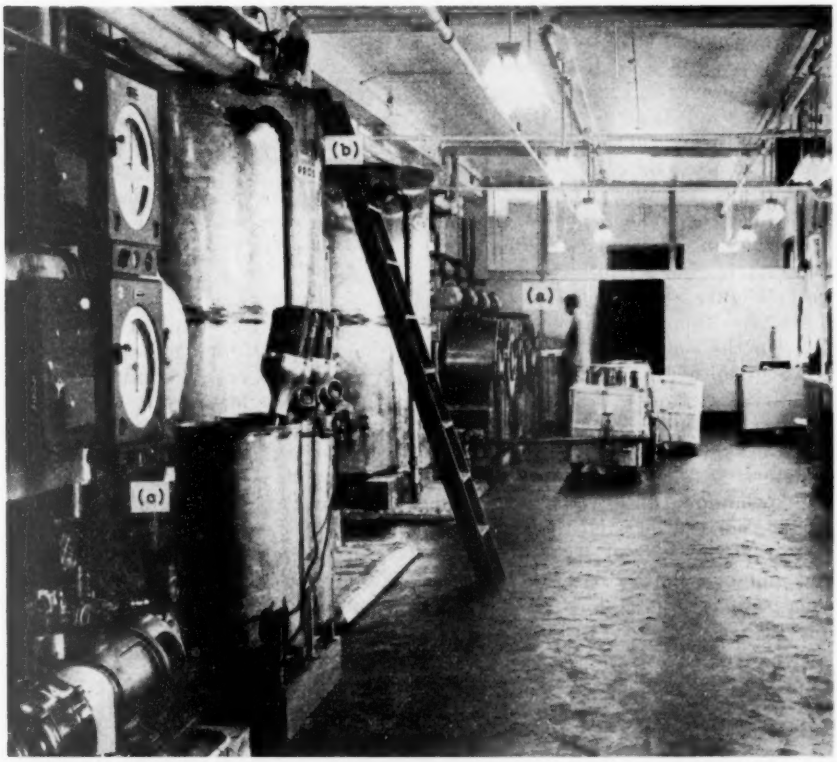


FIGURE 1.—Pilot plant for flotation treatment of laundry waste for re-use, showing: (a) four 25-lb. automatic washers and extractor, (b) storage and ballast tanks, and (c) controllers and chemical make-up tanks for clarifier.

veloped earlier and was readily available in a fair degree of perfection, but it had never been applied to laundry wastes being clarified for re-use. Chemical procedures had been used before on laundry waste water, but water so clarified was always discarded. As a result of this study, chemical procedures have been developed which will clarify soap-based laundry waste water in flotation equipment such that the clarified effluent can be continuously re-used and reclarified.

Early experiments involved the use of lime. Although lime is an effective coagulant for soap-based laundry waste water, the resultant effluent is too hard to be re-used in laundering without softening, which might be impractical in the field. Copperas was found to be an effective coagulant, but water containing this product is colored by the presence of iron oxide and cannot be used in laundering without discoloring the laundered load. Coagulation with cationic surface-active agents was successfully accomplished on a laboratory scale, but the cost was excessive. Acceptable clarification of laundry waste water was also obtained with alum and activated silica. The use of this combination, however, because of the requirements for critical control, was regarded as too complicated for practical application in the field.

The procedures finally chosen were first refined in laboratory equipment and then applied to large-scale pilot-plant equipment (Figure 1) installed in an assigned area of the Boston Naval Shipyard. The pilot plant consists of four 25-lb. capacity automatic washwheels, a ballast tank for waste-water flow and chemical equalization, a storage tank (Figure 2) for the clarified effluent, and a Gibbs-type flotation unit (Figure 3). All equipment was built by The Prosperity Company, Inc., to the cooperative design of the F. S. Gibbs Corporation, American Conditioning House, Inc., and the Department of the Navy, Bureau of Yards and Docks.

Referring to the flow diagram (Figure 4), laundry waste water generated by the four washers and the single extractor is collected in the dump tank and pumped to the ballast tank for equalization, a filter being used in the line to remove lint.

The clarification process begins with the introduction of waste water from the ballast tank to the premix tank. An alum solution is added directly into the pipe at the outlet of the ballast tank. Its addition is controlled by a pneumatic valve automatically positioned by a pH recorder-controller. A neutralizer, soda ash or caustic soda as the case may be, is similarly added, downstream from the alum addition, by a pneumatically-controlled valve also activated by a pH recorder-controller. Flow from the ballast tank to the clarifier is regulated automatically to any preset level by a Kates regulator. The coagulant-waste water mixture is fed to a premix tank to allow sufficient floc formation time and is then fed by gravity into the clarifier itself.

The clarifier (Figure 5) comprises, basically, two chambers, a flocculation chamber and a clarification chamber. Water to be clarified, containing co-

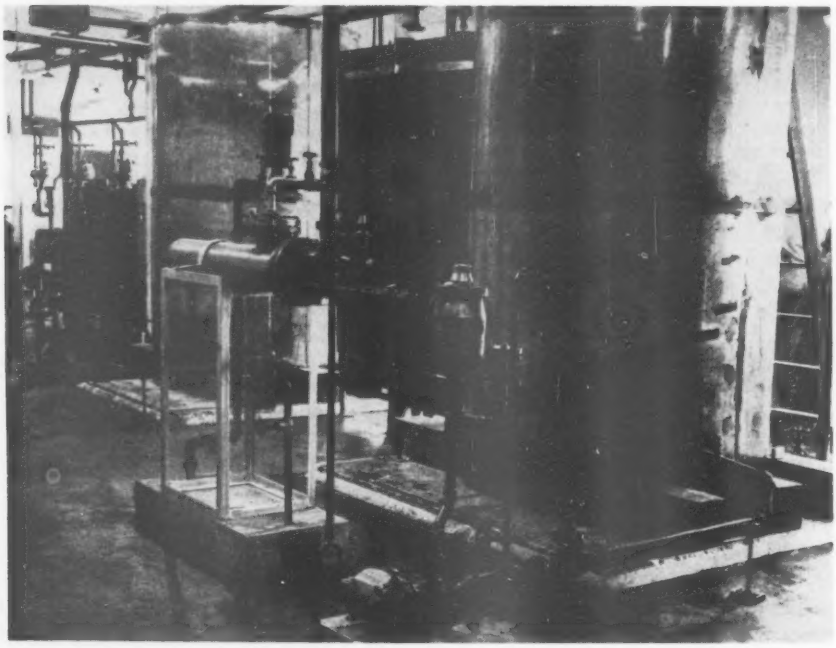


FIGURE 2.—Storage and ballast tanks, with flow controls and heat exchange system.

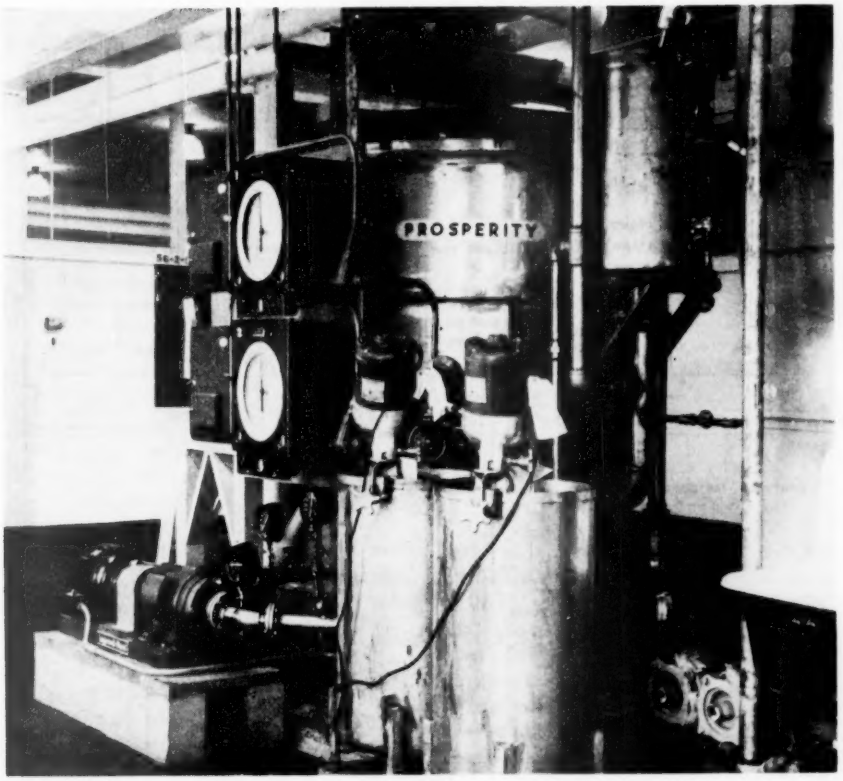


FIGURE 3.—Clarifier (large tank), premix tank (upper right), chemical make-up tanks (foreground), and chemical feed controllers (left).

agulant and neutralizing chemicals previously added, is fed continuously into the bottom of the flocculation chamber. As it rises, additional floc growth takes place. When it emerges from the upper edge of the flocculation chamber into the clarification or flotation chamber, it is met by a constantly rising, diffused mass of finely divided air bubbles. These bubbles associate themselves with the floc particles and both rise to the surface of the chamber, where the mass forms a cuff or sludge. The sludge, continuously scraped from the surface of the flotation chamber by a set of rotary scraper blades driven by a variable-speed drive just above them, is scraped into a well and is piped outside of the clarifier by gravity to a sludge container, or to whatever drain facilities are available.

The clarified effluent proceeds in a downward direction, emerges into an annular space near the bottom of the unit, and rises to the top for withdrawal over a circular weir by which the level in the clarifier is controlled. Flow out of the unit into a receiving trough is by gravity on an overflow basis. The effluent is then pumped to the storage tank for re-use in laundering.

The air bubbles for flotation are made by sucking air through a porous ceramic cylinder located on the suction side of a recirculating pump. This pump draws liquid from the bottom of

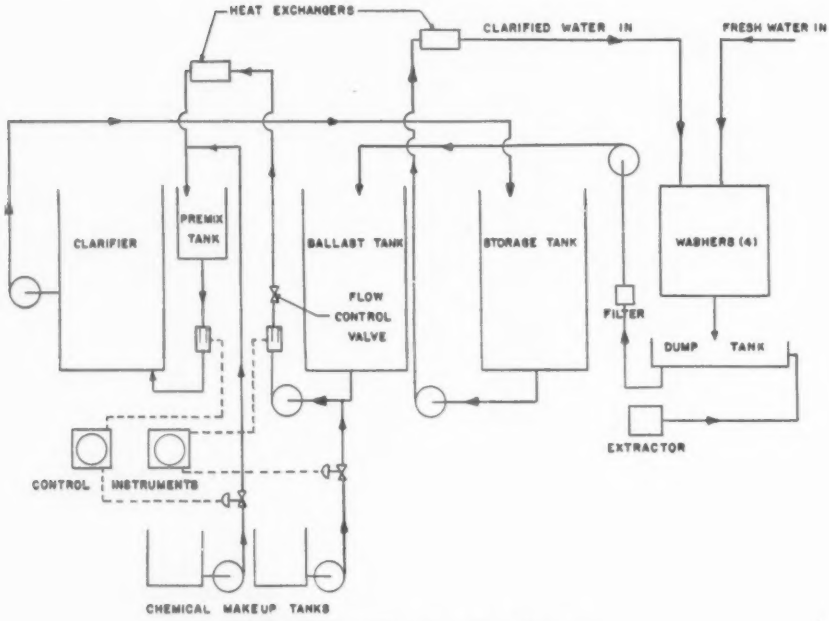


FIGURE 4.—Pilot-plant flow diagram.

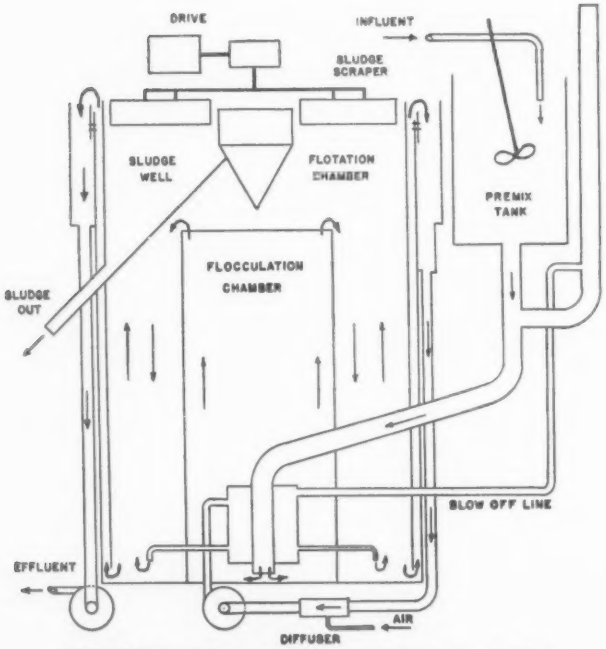


FIGURE 5.—Schematic diagram of flotation clarifier.

TABLE I.—Laundering Formula

Step No.	Time (min.)	Approx. Water Input (gal.)	Water Temp. (°F.)	Supplies
(1) 1st suds	4	10	160	52 gm. soap,[1] 107 gm. alkali[2]
(2) 2nd suds	3	7	160	20 gm. soap
(3) 3rd suds	4	7	160	8 gm. soap
(4) 4th suds	3	7	160	2 gm. soap
(5) Bleach	4	7	160	340 gm. 1% bleach
(6) 1st rinse	1:20	14	160	
(7) 2nd rinse	1:20	14	160	
(8) 3rd rinse	1:40	14	160	
(9) 4th rinse	1:40	14	160	
(10) Sour	2:40	7	160	13 gm. sour[3]
(11) Blue	2:20	14	40	85 gm. blueing
Total	29	115		

[1] Simplex.
[2] Perlite.
[3] Neutrogen.

the receiving trough. Auxiliary heat exchangers, pumps, and tanks shown in Figure 4 are used for obvious reasons.

Results

In experimental operation of the pilot plant on soap-based waste water, a nine-step laundering formula was used (Table I). Soiled clothes for the experiments were those of naval personnel and installations as they arrived in the adjacent Ships' Service Laundry. Although the last step in the laundering sequence, the fresh-water rinse, plays an important role in reducing residual salt concentration on the clothes, its main purpose, as in all laundering formulas, is to cool the clothes so that they can be handled manually. Since the formula was prescribed by others for use in this study, no attempt was made to overcome this expenditure of fresh water. A certain minimum will always be required, but it is quite possible that the water saving of 87 per cent referred to earlier can be further increased to 95 per cent by reducing the amount of fresh water used in the last rinse.

The first chemical procedure refined in the laboratory for pilot-plant testing was a straight alum-soda ash operation. While batch-wise clarification without re-use was quite successful, continuous clarification for re-use created difficulties caused by high bicarbonate alkalinity in the re-used fluid. Since pH was used as the parameter for operation of the pneumatic control valves, any chemical buffer present would of course cause the instrumentation system to be insensitive to additions of an acid salt such as alum. It was a corollary that as more and more alum was added to overcome the bicarbonate alkalinity in the waste water, more and more soda ash had to be added to effect subsequent neutralization. Each chemical addition, therefore, aggravated an already bad situation, having the effect of a constantly rising bicarbonate alkalinity (Figure 6), a constantly rising soluble solids content (Figure 7), and a constantly rising chemical consumption (Figure 8), as the continuous clarification for re-use run progressed. This effect was successfully overcome by the substitution of caustic soda for soda ash as the neutralizing chemical. Subsequent experiments indicated the wisdom of this substitution.

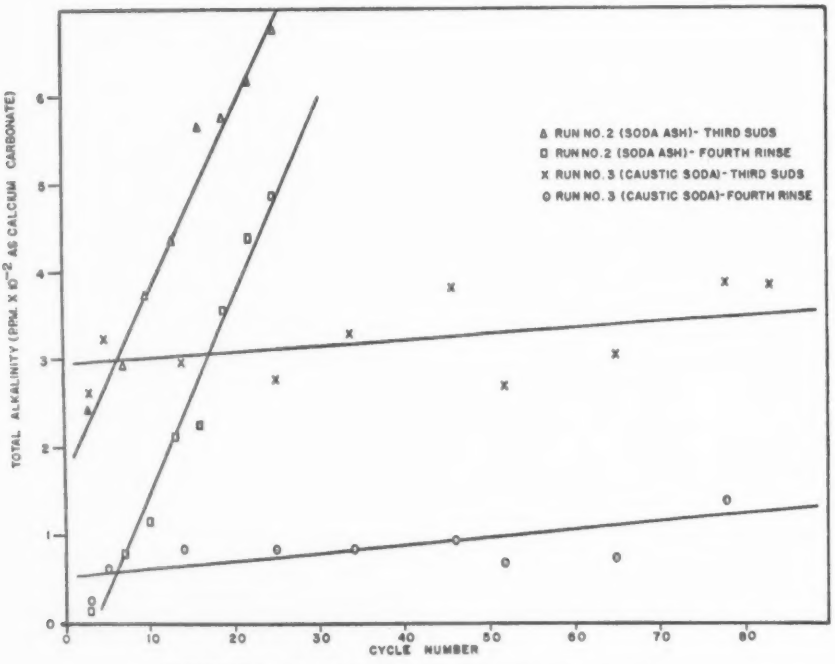

TOTAL ALKALINITY (EPM. X 10^{-2} AS CALCIUM CARBONATE)
CYCLE NUMBER
Δ RUN NO. 2 (SODA ASH)- THIRD SUDS
□ RUN NO. 2 (SODA ASH)- FOURTH RINSE
× RUN NO. 3 (CAUSTIC SODA)- THIRD SUDS
○ RUN NO. 3 (CAUSTIC SODA)- FOURTH RINSE

FIGURE 6.—Total alkalinity in washwheel dump water.

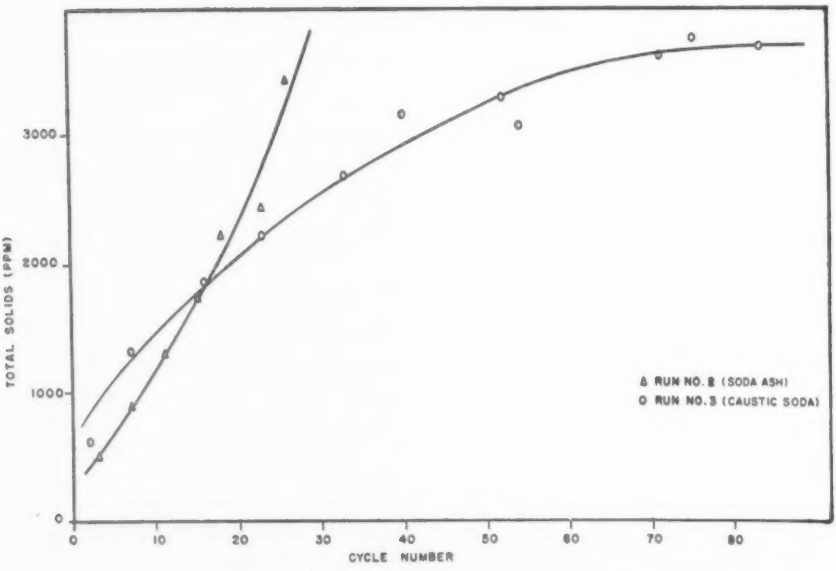


FIGURE 7.—Total solids in clarified waste water.

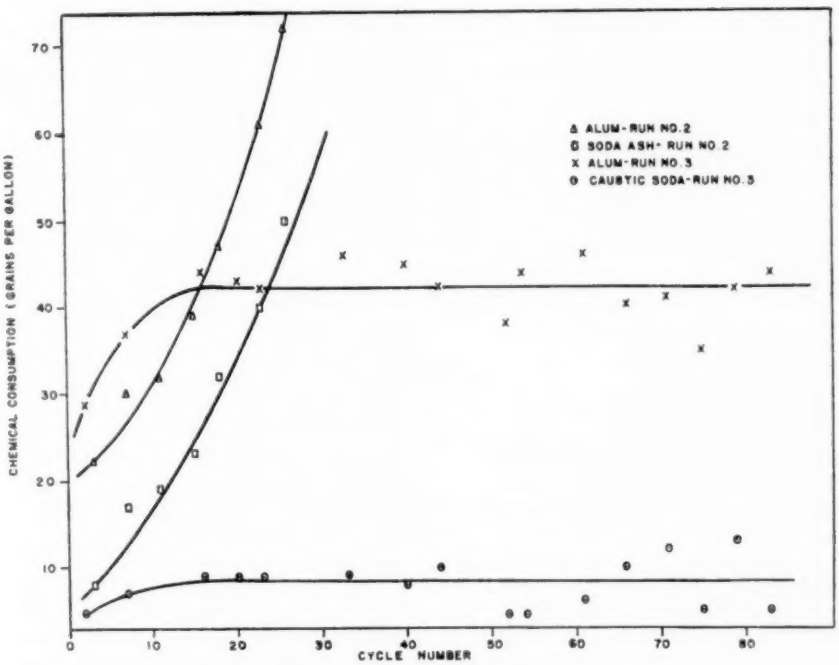


FIGURE 8.—Average chemical consumption.

A two-week run was successfully carried out wherein 83 laundering cycles of 4 loads each, or 332 loads of clothes, were laundered. Without water reuse this would require 115 gal. for each load, or a total of 38,000 gal. By using the clarification system, 5,000 gal. were actually consumed. Total alkalinity, solids in solution, and chemical requirements all leveled out as the run progressed (Figures 6, 7, and 8).

At intervals during the run, samples of the clarified effluent were tested for clarity in a colorimeter and hardness measurements were made. These measurements indicated that clarity was comparable with hot tap water. Hardness measurements showed that the effluent consistently gave results equal to or better than Boston city water, which averages 18 p.p.m. as calcium carbonate.

To determine the effectiveness of laundering during this experimental run, samples of white sheeting known as "Wamsutta test cloth" were washed for various lengths of time, in consecutive wash loads in one washwheel. Whiteness retention measurements were made on a reflectometer. Results (Table II) indicated satisfactory laundering throughout as far as whiteness was concerned. Ash determinations (Table II) were also made on samples of this fabric, which indicated that there was no substantial buildup of inorganic salts on the clothes.

The equilibrium chemical consumption was approximately 40 grains of alum and 9 grains of caustic soda per gallon. The total chemical cost of these dosages was of the order of $0.25 per 1,000 gal. The alum costs might possibly be reduced by as much as 40 to 60 per cent if sulfuric acid instead of alum were used to reduce the pH of the waste water part way.

One of the additional features of

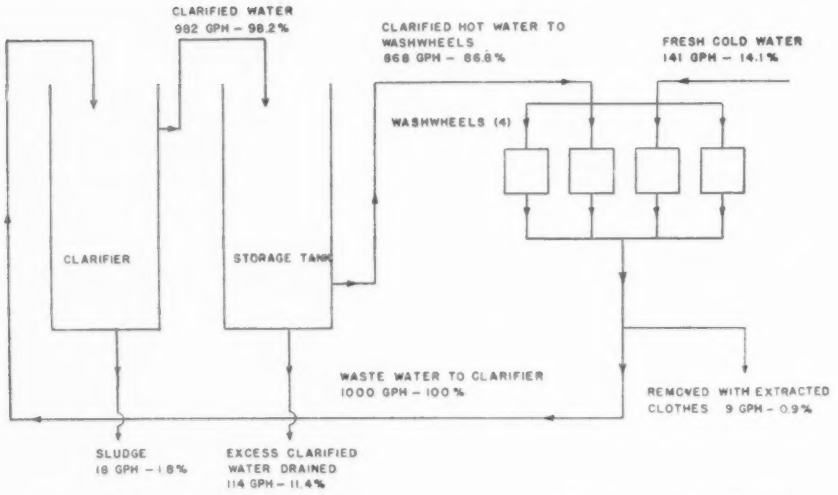


FIGURE 9.—Pilot-plant water balance on the basis of 1,000 g.p.h. to the clarifier.

this recovery system is the heat savings made. Although they were not a primary objective in the study, they were an adventitious dividend. In laundries everywhere one of the greatest offenders is heat loss in the washer, from which large quantities of hot waste water are ordinarily discarded. Although heat exchangers are sometimes used, they are less efficient than the direct contact, heat recovery method employed in this clarification and re-use system. Clarified water is re-used directly in the washwheel and the heat input beyond initial start-up is only that required to overcome line losses and the effect of the cold, fresh-water rinse, the last step in the laundering cycle. In experimental operations, the temperature in the washers was 160° F., which dropped to 130° F. after clarification. Under these conditions and an input line temperature of 40° F., heat recovery was in excess of 70 per cent.

TABLE II.—Whiteness Retention and Ash Values

Cycle No.	Times Washed	Whiteness Retention[1] (%)	Ash[2] (%)
1–83	83	96.0	0.20
1–25	25	96.5	0.16
26–83	58	97.4	0.19
53–75	23	98.7	0.17
10	1	98.6	0.13
26	1	98.2	0.16
77	1	97.2	0.18

[1] Average of eight measurements: whiteness retention of original fabric = 100 per cent.

[2] Average of two determinations: ash of original fabric = 0.21 per cent.

Figure 9 shows the distribution of input and output under the conditions of pilot-plant operation already described. Thus, the clarifier by itself operated at a recovery efficiency of 98.2 per cent and the pilot plant as a whole at a water recovery efficiency of 86.8 per cent.

The pilot plant was experimentally operated at 13 g.p.m., or 780 g.p.h. The clarifier operated at a rate of 1.04 g.p.m. per square foot of surface area. The pilot plant was designed to operate at a maximum of 40 g.p.m., or 2,400 g.p.h., and the clarifier at 3 to 6 g.p.m. per square foot of surface area. The maximum capacity of the pilot unit has not yet been determined, although it is possible that the upper limit is of the order of 75 g.p.m.

Conclusion

It is evident from these studies that a practical method has been developed for the clarification and re-use of soap-based laundry waste water. The ability to recover continuously for re-use 87 per cent of the water requirements in laundering has been demonstrated and the possibility of recovering up to 95 per cent has been projected. It is believed that these developments are of major importance to the Navy Department in its program for reducing water consumption in outlying bases and in those areas of the continent where fresh water is in short supply.

The principles that have been developed, it is believed, can be readily applied to recovery of waste water from other sources. It is hoped that this work, while of immediate importance to the armed forces, represents a significant contribution to the waste treatment field.

References

1. Rudolfs, W., "Industrial Wastes." Reinhold Publishing Corp., New York, N. Y. (1953).
2. Gehm, H. W., "Volume Characteristics and Disposal of Laundry Wastes." *Sewage Works Jour.*, **16**, 3, 571 (May, 1944).
3. Boyer, J. A., "Treatment of Laundry Wastes." *Texas Eng. Sta. Bull.*, **4**, 6 (Oct., 1933).
4. Eliasson, R., and Schulhoff, H. B., "Laundry Waste Treatment by Flotation." *Water and Sewage Works*, **90**, 418 (1943).
5. Anon., "Experimental Pilot Plant Studies in the Treatment of Laundry, Milk and Restaurant Wastes." Florida State Board of Health, Bur. of San. Eng. (Apr., 1953).
6. Newell, J. F., Christenson, C. W., *et al.*, "Laboratory Studies on Removal of Plutonium from Laundry Wastes." *Ind. Eng. Chem.*, **43**, 1516 (1951).
7. McCarthy, J. A., "A Study of Laundry Waste Treatment." *Pub. Works*, **73**, 7, 13 (1942).
8. Schwarz, A. M., "The Structural Characteristics and Behavior of Modern Surfactants." Paper presented before Div. of Water, Sewage and San. Chem., A.C.S. (Apr., 1951).
9. Waddams, A. L., "Synthetic Detergents and Sewage Processing." *Jour. and Proc. Inst. Sew. Purif.*, Part I, 32 (1950).
10. Stericker, W., and Middleton, A. B., "Detergent Properties and Their Effect in Sewage and Water Treatment," Paper presented before Div. of Water, Sewage and San. Chem., A.C.S. (Apr., 1951).
11. Anon., "Effect of Detergents on Sewage and Water Treatment," *Chem. Eng. News*, **31**, 1072 (1953).
12. Kalinske, A. A., "Comparison of Flotation and Sedimentation in the Treatment of Industrial Wastes." Proc. 8th Ind. Waste Conf., Purdue Univ. (1953).
13. D'Arcy, N. A., Jr., "Dissolved Air Flotation Separates Oil from Waste Water." Paper presented at 16th Midyear Meeting, Amer. Petroleum Inst., Div. of Refining (1951).
14. Gibbs, F. S., "Unique Flotation Unit for Industrial Waste Treatment." *Water and Sewage Works*, **97**, 241 (1950).
15. Gibbs, F. S., "The Removal of Fatty Acids and Soaps from Soap Manufacturing Waste Waters." *Proc. 5th Ind. Waste Conf.*, Purdue Univ. (1950).
16. Barry, A. I., "Diffused Air Particles for Waste Disposal." *Chem. Eng.*, **58**, 4, 107 (1951).
17. Easton, P., "Sveen Pederson Savealls in Board Mills." *Paper Trade Jour.*, **129**, 37 (Aug., 1949).

DEEP-WATER DISPOSAL OF PULP MILL WASTES INTO PORT GARDNER BAY, EVERETT, WASHINGTON

By Gerald T. Orlob * and E. F. Eldridge

Respectively Assistant Professor of Civil Engineering, University of California, Berkeley, Calif., and Director, Washington Pollution Control Commission, Olympia, Wash.

A water quality survey in the Everett Harbor area in 1949 (1) demonstrated the existence of a definite barrier to the normal migration of salmon in the lower estuary of the Snohomish River at its entrance into Port Gardner Bay (see Figure 1). Since the Snohomish River supports a salmon fishery valued at more than $4,000,000 annually, it was important to the economy of that area that this barrier be removed. The barrier consisting of an oxygen-deficient mass of water confined within the river channel, was caused by the organic waste discharges of two large sulfite pulp mills situated at the river mouth, domestic sewage from the city of Everett, and wastes from numerous small industries. During the summer months when stream flows were low, and at a time when fingerling salmon were migrating to salt water through the brackish estuaries, flooding tides caused the intrusion of oxygen-deficient water into the mouth of the river. Here, in a restricted section through which both upstream and downstream migrants had to pass, oxygen concentrations were almost continually unsatisfactory. Concentrations of spent sulfite liquor (S.S.L.), arising from the pulp mill discharges, were correspondingly high. Under certain conditions of tide, river flow, and waste discharge, up to 5 mi. of river channel was deficient in the dissolved oxygen considered necessary to sustain fish life (5.0 p.p.m.)

Similar conditions, although not so severe or so frequent in occurrence, were observed in the channel of Steamboat Slough, another major branch of Snohomish estuary, which enters salt water a few miles north of Port Gardner Bay.

On April 6, 1951, the two sulfite pulp mills located in Everett placed in operation an underwater disposal line capable of dispersing 22 m.g.d. of concentrated digester liquor and wash waters through a series of outlets over a 1,000-ft. section at a depth of 300 ft., in Port Gardner Bay. The project, costing approximately $625,000, was undertaken as a result of orders issued by the Washington Pollution Control Commission on February 2, 1950, directing the mills to eliminate or alleviate conditions ascribed to the discharge of their waste materials to adjoining receiving waters.

Plans for the construction of the dispersal line were accepted and approved by the Commission in September, 1950, with the following provisions:

1. "That the method of deep water disposal accomplished by this project does not constitute a permanent solution for the sulfite waste disposal problem . . . ," and
2. That the two Everett pulp mills ". . . continue . . . efforts to provide a recovery process or some other means of eliminating sulfite waste liquor as a pollution factor in Port Gardner Bay. . . ."

* Formerly Survey Engineer, Washington Pollution Control Commission, Olympia, Wash.

The two mills responded to these provisions, indicating that both had instituted research on methods of eliminating or reducing wastes by process conversions. Methods under consideration involve changing the pulping base from calcium to either ammonia or magnesium, with subsequent recovery of the base chemical, sulfur, and heat for steam power generation. Production-scale operations on both base conversions are being studied, but there are a number of obstacles to be overcome before either process may be employed in the Everett mills. The major obstacle is that of financing. In

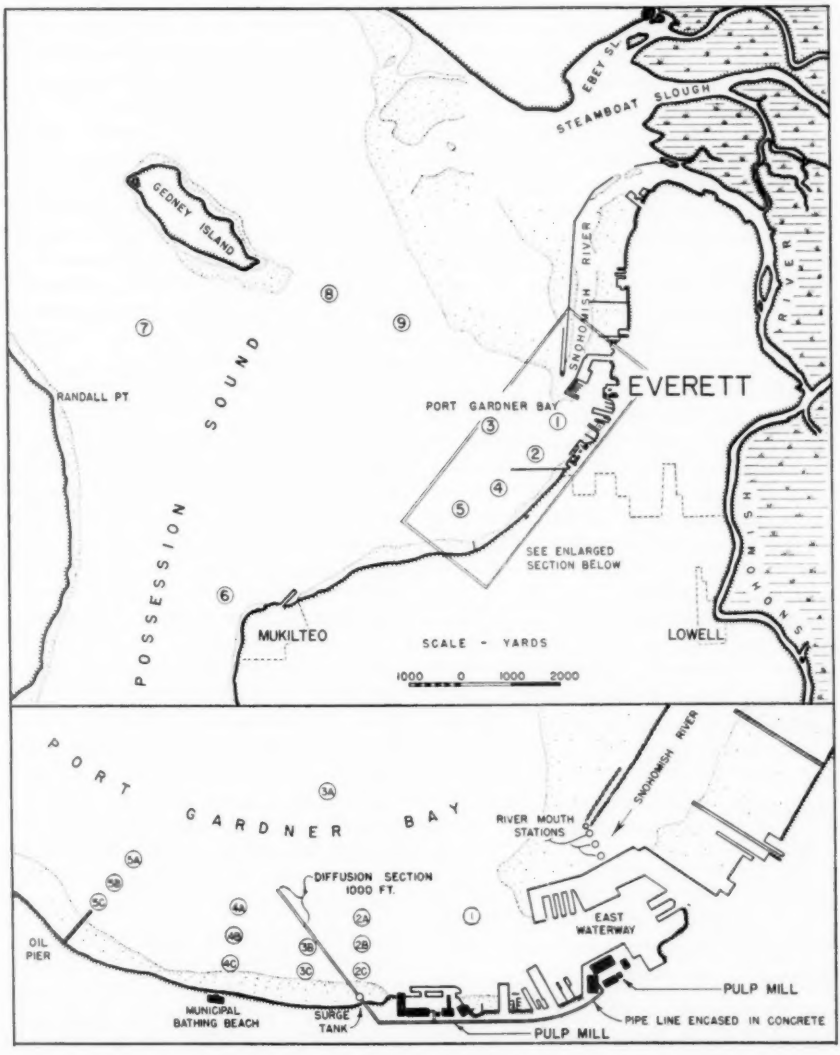


FIGURE 1.—Port Gardner Bay and the lower Snohomish River, showing the survey and sampling stations; June–July, 1951.

addition, priority allocation of critical materials, such as high-quality stainless steels, has made almost impossible the acquisition of the equipment required for conversion to an ammonia or magnesium base system. Recent improvements in this situation, however, are encouraging.

In view of these problems, the two pulp mills proposed the installation of the deep-water disposal line (see Figure 1) as a cooperative venture. It was constructed of creosote-impregnated wood staves, banded with stainless steel, and equipped with a multiple-diffuser section 1,000 ft. in length. The line was encased in concrete throughout the section connecting the two mills, provided with a surge tank, and entered Port Gardner Bay at a point approximately 7,000 ft. from the mouth of the Snohomish River. It was believed that this location, the unusual depth at which discharge was to occur, and the multiple diffuser design would combine to provide sufficient dilution of the waste to prevent the occurrence of high concentrations of S.S.L. in the river channel.

The purpose of the investigation reported herein was two-fold. First, it was desired to determine to what extent the migration barrier on the Snohomish River was reduced by deep-water disposal. A second objective of the survey was to determine in a general manner the disposition of the waste liquor in the waters of Port Gardner Bay and adjoining Possession Sound.

Migration Barrier—Comparison of 1949 and 1951

The formation and persistence of a pollution barrier to the effective migration of salmon through the Snohomish River channel depends upon a number of factors. Among these are:

1. The concentration of oxygen-consuming organic matter carried in the waters of the Snohomish River and Port Gardner Bay in the vicinity of the river mouth. (Waste discharges to the bay remain relatively constant throughout the year.)

2. The action of tides, which restricts the river discharge and tends to carry the harbor water into the confined river channel. (Tides in Puget Sound are of a mixed type, consisting of one major and one minor ebbing-flooding cycle each lunar day. Flooding tides have been shown to carry salt water upstream in the Snohomish as much as 7 mi. from its mouth (1). Salt water may remain confined within the estuary for as long as 18 hr., after which complete flushing occurs.)

3. River discharge, which resists the upstream advance of tidal waters. (Hydrographic data for the Snohomish system indicates that minimum flows which permit greatest salt water intrusions occur during the months of August and September, when salmon migration is at its peak.)

4. Water temperature, upon which the solubility of oxygen in water and the rate of oxygen consumption depend. (High water temperatures, occurring coincident with minimum stream flows in the late summer, decrease oxygen solubility and increase the rate of biological activity resulting in lowered dissolved oxygen.)

5. Wind action and channel characteristics, which affect the ability of polluted waters to restore oxygen deficits by reaeration from the atmosphere. (Because the Snohomish channel is confined by a training dike running in a north-south direction, only winds along its axis have an appreciable effect on the water. During the summer months the prevailing winds in this area are usually from the northwest.)

In the case of the Snohomish River channel, the concentration of organic wastes (item 1) is the one factor over which man may exercise significant control. The problem of an oxygen-deficient barrier in the Snohomish River would, of course, be non-existent

if there were no discharges of organic material to the river and Port Gardner Bay. Since it is not possible to entirely eliminate the discharge wastes to the river and harbor, a partial solution would be to reduce the major fraction of the pulp mill waste by instituting waste liquor recovery processes, and to provide primary treatment for the domestic sewage from the city of Everett.

Pending this more permanent solution to the problem, the dispersion or distribution of wastes through such a large volume of water that waste concentrations are seldom great enough to cause substandard dissolved oxygen conditions will tend to substantially alleviate the conditions. This is the method by which Everett's two sulfite pulp mills are seeking to relieve the grossly-polluted condition that has existed in Everett's harbor and the mouth of the Snohomish River for a number of years.

In an effort to determine in a general way the efficiency of this dispersal line in reducing waste liquor concentrations to a satisfactory level, the Washington Pollution Control Commission made a resurvey of the area in June, 1951. The results of the surveys on two typical days—June 19, 1951, and September 29, 1949—may be used to demonstrate the effect of the disposal method.

On June 19, 1951, a series of samples were collected through a critical tidal movement at the mouth of the Snohomish River. Twenty-nine samples were taken over an 8-hr. period at the surface and bottom of the channel from stations near the east and west banks of the river and at mid-channel. Each sample was analyzed for dissolved oxygen, spent sulfite liquor concentration, and chloride content. A summary of the results of this analysis revealed that on no occasion was the dissolved oxygen recorded at less than 5 p.p.m., which is considered the minimum desirable concentration. Sulfite waste liquor concentrations reached a maximum of 76 p.p.m., with nearly two-thirds of the samples showing less than 25 p.p.m. Average liquor concentration was computed to be 22.2 p.p.m., whereas the dissolved oxygen concentration averaged 8.18 p.p.m.

To gage the degree of improvement in water quality at the mouth of the Snohomish, the data collected on the survey described above may be compared to data collected under similar conditions on September 29, 1949, before the dispersal line had been installed. Spent liquor discharges remained substantially unchanged from 1949 to 1951. On this former occasion, 53 samples were collected at the same locations in the river mouth and similarly analyzed. In the 1949 investigation, no sample revealed a dissolved oxygen content greater than 5 p.p.m., and S.S.L. concentrations were recorded as high as 650 p.p.m. About one-third of all samples contained less than 1 p.p.m. of dissolved oxygen; the average was 2.04 p.p.m. Waste liquor concentrations averaged 180 p.p.m. Tables I and II summarize these two groups of data in a comparative manner and also give the other pertinent data relating to collection of samples.

It should be noted, in view of the factors which influence the formation of an oxygen deficient barrier in the Snohomish channel, that the river discharge was considerably greater during the recent survey, a factor which would tend to favor dispersal line operation. The fact remains, however, that during the months of June and July, 1951, at a time when migratory salmon, both upstream and downstream, were presumed to have been in the estuarial area, no evidence of an oxygen deficiency barrier to migration was observed. Of significance, also, was the apparent absence of fish kills in the vicinity of the river mouth and inner harbor during the 1951 investigation. The survey crew was in the area for more than two months

TABLE I.—Summary of Dissolved Oxygen Conditions at Mouth of the Snohomish River, 1949 and 1951 [1]

Item	Sampling Period			
	Sept. 29, 1949[2]	June 19, 1951[3]	Entire 1949 Survey	Entire 1951 Survey
No. samples	53	29	71	35
D.O. samples (%):[4]				
1 p.p.m.	34.0	0	25.4	0
2 p.p.m.	47.2	0	35.2	0
3 p.p.m.	71.7	0	63.4	0
4 p.p.m.	96.2	0	84.6	0
5 p.p.m.	100	0	92.9	0
6 p.p.m.	100	6.9	98.7	14.3
7 p.p.m.	100	20.7	98.7	22.9
8 p.p.m.	100	31.0	100	37.1
9 p.p.m.	100	58.7	100	74.3
10 p.p.m.	100	100	100	100

[1] Before and after pulp mill waste pipeline was placed in operation.

[2] River discharge, 1,988 c.f.s.; sampling period, 5:30 AM to 4:25 PM; low tide − 0.5 ft. at 4:00 AM, high tide + 10.3 ft. at 11:43 AM, low tide + 7.3 ft. at 5:05 PM; temperature range, 11.7° to 13.6° C.

[3] River discharge, 8,710 c.f.s.; sampling period, 11:25 AM to 7:40 PM; low tide − 4.2 ft. at 11:14 AM, high tide + 12.2 ft. at 6:55 PM, low tide + 8.1 ft. at 11:48 PM; temperature range, 11.0° to 16.5° C.

[4] Percentage of samples containing D.O. concentration equal to or less than value.

during the critical period, but on no occasion did any member of the group note any visual manifestation of the effect of pollution on the higher forms of aquatic life. However, during the same seasonal period of the 1949 survey, numerous kills of herring, candlefish, and even adult salmon were observed. In several instances, schools of small fish were trapped within the river channel or the inner harbor area by masses of oxygen-deficient water, impounded by flooding tides. Several of these kills were definitely proven to have been caused by organic waste materials, principally spent sulfite liquor, which in the process of biochemical oxidation caused a depletion of dissolved oxygen in the water.

Pollution Conditions in the East Waterway

During the previous survey (1949, before the line was in operation) a

TABLE II.—Summary of Spent Sulfite Liquor Concentrations at Mouth of Snohomish River, 1949 and 1951 [1]

Item	Sampling Period			
	Sept. 29, 1949[2]	June 19, 1951[3]	Entire 1949 Survey	Entire 1951 Survey
No. samples	53	29	71	36
S.S.L. samples (%):[4]				
Tr.—10 p.p.m.	100	41.4	100	52.8
25 p.p.m.	100	31.0	98.7	38.9
50 p.p.m.	88.8	17.2	88.6	16.7
75 p.p.m.	69.8	3.5	73.2	2.8
100 p.p.m.	67.8	0	70.4	0
150 p.p.m.	45.3	0	43.7	0
200 p.p.m.	37.7	0	29.6	0
300 p.p.m.	18.9	0	14.1	0
500 p.p.m.	5.7	0	4.2	0
600 p.p.m.	1.9	0	1.4	0

[1,2,3] See footnotes Table I.

[4] Percentage of samples containing S.S.L. concentrations equal to or more than value.

number of samples were taken in the East Waterway (see Figure 1) in the vicinity of one of the pulp mills. Samples were collected from surface, bottom, and intermediate elevations of each of five principal stations within the waterway. Because of the proximity of these stations to the mill outfall, most analyses indicated extremely high concentrations of S.S.L. and correspondingly low dissolved oxygen content. This was particularly true of those samples taken from the surface strata.

Average spent liquor concentration for samples taken in 1949 was 527 p.p.m., with a range from 23 p.p.m., for a bottom sample near the west edge of the waterway, to 2,130 p.p.m. for the surface layer near the pulp mill pier. Generally, surface concentrations were from 10 to 20 times as great as values determined for bottom samples at the same location.

Dissolved oxygen for the 1949 samplings in the East Waterway ranged from 0 to 4 p.p.m., with an average content of 1.8 p.p.m. Bottom samples indicated an average of 3.1 p.p.m., while at the surface a majority of samples were completely devoid of oxygen.

The 1951 investigation following the pipeline installation revealed some in-

teresting contrasts. Waste liquor concentrations, for example, averaged only 164 p.p.m., with a range from 115 to 260 p.p.m. In several cases there was little difference between top and bottom concentrations; in some others, particularly those closest to deep water, the bottom samples revealed higher S.S.L. content.

Oxygen concentrations during the resurvey were slightly improved on the average, but still were much below the standard 5 p.p.m. Bottom conditions were considerably more critical than was previously noted. An average of only 0.5 p.p.m. was recorded for bottom samples at all stations in the waterway. An average D.O. of 2.05 p.p.m. was recorded for all samples taken in this area. Table III is a summary of data collected in the inner harbor area for each of the two years under comparison.

Observations of bottom sediment during the 1949 investigation revealed that most of the harbor bottom was covered with a blanket of decomposing organic matter. Hydrogen sulfide odors and the presence of various marine seavenger worms, or the complete absence of any marine life, emphasized the severity of this pollution phenomenon. It is probable that this layer of sludge, which was noted to be high in organic content, has been substantially increased during the two-year period between the two surveys. Several of the recent samplings of the bottom strata for D.O. and S.S.L. in the East Waterway revealed strong hydrogen sulfide odors, with a corresponding absence of dissolved oxygen. These observations suggest that at least part of the oxygen is removed by decaying fiber, wood waste, sewage solids, fish cannery waste, and like materials, which lie on the harbor bottom.

If fiber losses from the two pulp mills are estimated at 0.5 per cent of the total production, suspended organics from these sources alone would amount to more than 4 tons daily. Several Everett domestic sewers and a fish processing establishment provide additional quantities of organic material.

Results of Deep-Water Sampling in Everett Harbor

Another objective of the 1951 investigation was to determine in a general manner what became of the sulfite waste liquor discharged through the deep-water disposal line. It was likewise important to establish whether this mode of disposal is likely to significantly affect the resident or migrant fish populations in the vicinity of the outfall. The complete answer to either of these problems cannot be secured in so short an investigation as that undertaken in the summer of 1951, and it may actually be several years before the full effect of this discharge is manifested.

In the first stages of the 1951 survey, a series of sampling stations was located along the south shoreline in the vicinity of the outfall (see Figure 1). To obtain information on the extent of S.S.L. pollution, samples were collected at these stations at depths ranging to 80 ft. below the water surface.

TABLE III.—Dissolved Oxygen and Spent Sulfite Liquor Concentrations, Inner Harbor Area, 1949 and 1951

Survey	Dissolved Oxygen (p.p.m.)				Spent Sulfite Liquor (p.p.m.)			
	Range	All	Surface	Bottom	Range	All	Surface	Bottom
1949	0.0–4.0	1.83	0.89	3.11	23–2,130	527	1,117	121
1951	0.0–5.0	2.05	4.00	0.50	115–260	164	165	178

TABLE IV.—Summary of Depth Samples in South Beach Area, June 20, 1951

Sta.	Dissolved Oxygen (p.p.m.)			Spent Sulfite Liquor (p.p.m.)		
	1-25 ft.	25-60 ft.	60-80 ft.	1-25 ft.	25-60 ft.	60-80 ft.
1	8.15[1]	0.90[1]	3.60[1]	13[1]	203[1]	180[1]
2B	8.2	3.5	2.3	17	190	270
2C	7.7	4.4	3.3	16	180	180
3B	7.8	4.0	0	18	820	2,760
3C	7.5[1]	5.3	—[2]	24[1]	155	—[2]
4B	7.7	6.5	0.6	21	95	580
4C	7.8	7.4[1]	—[2]	26	51[1]	—[2]
5B	8.4	8.1	6.2	15	tr.	35
5C	8.6	8.4[1]	—[2]	18	15[1]	—[2]
Av.	7.94	5.43	2.80	18.6	165	598

[1] Average of two samples.
[2] Depth less than 60 ft.

A summary of the results of these samplings is given in Table IV.

It is apparent that at the time of the first sampling, waste sulfite liquor from the diffuser line was not reaching the surface strata in significant concentrations, but was probably stratifying at a depth of 80 ft. or greater.

Subsequently, equipment which permitted the collection of samples from depths to 300 ft. was obtained and additional examinations were made at various stations throughout the harbor and adjoining Possession Sound. The results of these later samplings, summarized in Table V, confirmed the preliminary observations and indicated that sulfite waste liquor, after initial mixing with salt water at the bottom of Port Gardner Bay, was distributed in strata ranging in elevation from 50 to 200 ft. below the water surface. Waste liquor concentrations at these elevations were accompanied by correspondingly low dissolved oxygen content.

The phenomenon of stratification is further illustrated by a series of samples collected on a section transverse to the direction of the outfall line. Results of this series are plotted graphically in Figure 2, where lines of equal concentration are used to indicate the distribution of waste material and the variation in dissolved oxygen concentrations.

Consideration of the oceanographic characteristics of the harbor and its waters and the nature of the wastes being discharged through the diffuser line leads to a rather simple yet plausible explanation for the observed stratification. The problem resolves itself into one concerned with the interrelation between the densities of the waste, harbor waters, and waste-receiving water mixtures. In the ideal case of the relatively shallow ocean outfall discharging domestic sewage with a density only slightly greater than unity, the diluted sewage always rises to the

TABLE V.—Summary of Depth Samples (0 to 300 Feet) in Survey Area, June 25, 26, and July 16, 1951

Sta.	Dissolved Oxygen (p.p.m.)					Spent Sulfite Liquor (p.p.m.)				
	1-25 ft.	25-75 ft.	75-150 ft.	150-225 ft.	225-300 ft.	1-25 ft.	25-75 ft.	75-150 ft.	150-225 ft.	225-300 ft.
1	6.6[1]	5.0	2.5	—[2]	—[2]	35[1]	220	143	—[2]	—[2]
2A	6.75[1]	4.05[1]	3.25[1]	3.20[1]	0.8	26[1]	168[1]	178[1]	325[1]	185
3A	7.85[1]	2.8[1]	6.0[1]	5.0[1]	5.45[1]	14[1]	419[1]	169[1]	12[1]	tr[1]
4A	7.7[1]	5.45[1]	4.05[1]	5.2[1]	5.9[1]	13[1]	12[1]	217[1]	10[1]	12[1]
5A	6.55[1]	6.85[1]	4.50[1]	2.95[1]	3.00[1]	44[1]	59[1]	12[1]	129[1]	102[1]
6	8.55[1]	7.95[1]	7.25[1]	6.15[1]	5.5[1]	tr[1]	tr[1]	tr[1]	tr[1]	tr[1]
7	8.7	6.8	6.0	5.3	5.3	tr	tr	tr	10	tr
8	9.35[1]	6.85[1]	—[2]	—[2]	—[2]	tr[1]	12	—[2]	—[2]	—[2]
9	8.92[1]	6.97[1]	6.30[1]	5.30[1]	4.60[1]	10[1]	14[1]	13[1]	tr[1]	12[1]

[1] Average of two samples.
[2] Depth less than indicated.

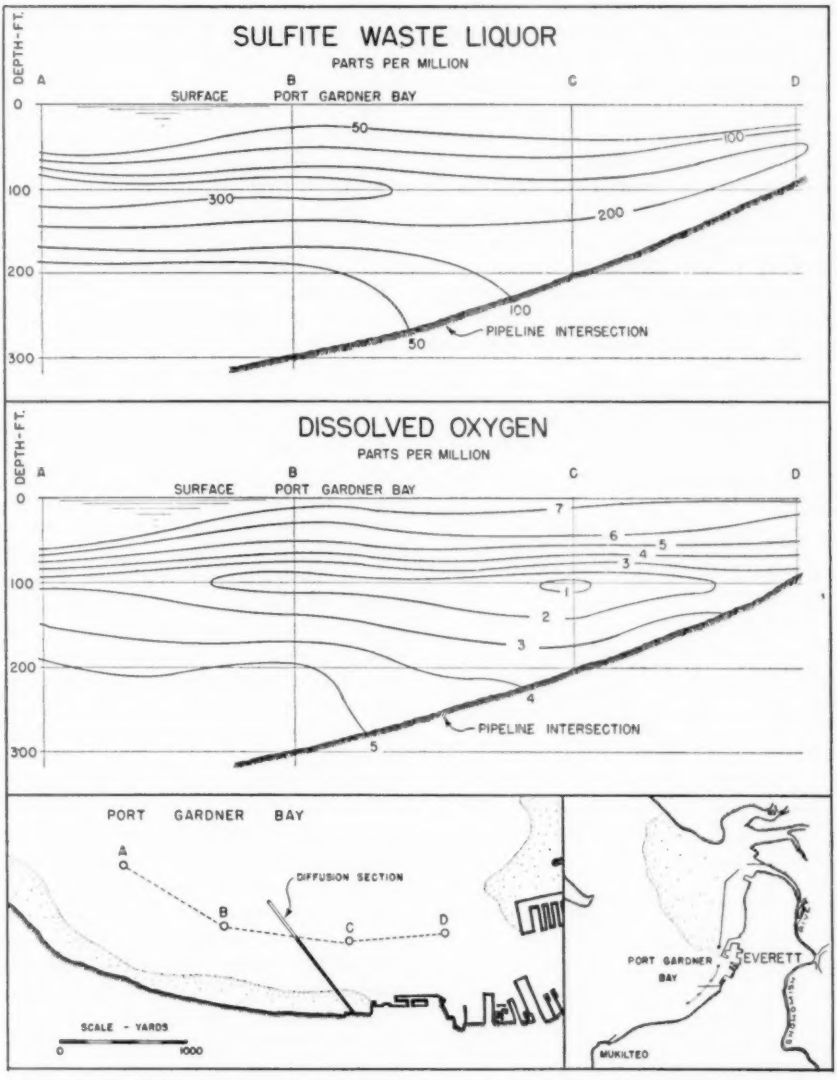


FIGURE 2.—Dissolved oxygen and sulfite liquor concentrations in Port Gardner Bay, from surface to 300-ft. depth on section across sulfite mill diffusion line. Samples taken at points A, B, C, and D during a 3-hr. period on June 25, 1951 as tidal elevation varied from + 4.2 ft. at 1 PM to + 1.8 ft. at 4 PM.

surface, because any mixture of waste and sea water will always have a density less than that of the surrounding water. Such is not the case with the Port Gardner Bay outfall, where waste-seawater mixtures actually cease to rise after initial dilution has occurred.

Salinity, temperature, and density gradients from the surface to the bottom of Port Gardner Bay are of sig-

nificance in this instance. Surface salinities fluctuate markedly with the stage of runoff of the Snohomish River, which discharges to salt water a little more than 1 mi. from the outfall site. At times of flood, surface waters may be almost entirely fresh, but even at low river stages surface salinities may be less than one-third that of normal sea water (approximately 19,000 p.p.m. as chloride ion). River discharges have little effect on harbor water below about 50 ft., thus only slight variations in the salinity of waters below this level are noted.

Thermal gradients are of relatively little importance in their effect on the density of harbor water, but they do tend to accentuate density differences.

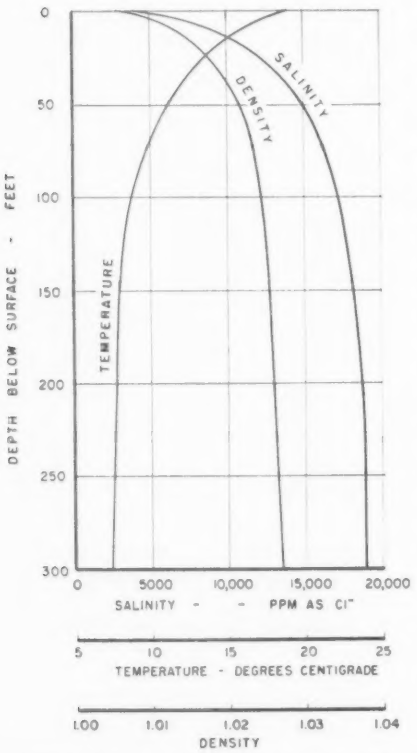


FIGURE 3.—Typical variations of salinity, temperature, and density with depth, Port Gardner Bay.

At times of low river flow, temperatures were noted to range from 19° C. at the surface to as low as 7° C. at a depth of 300 ft.

Density, which in this instance is largely a function of salinity, may vary from nearly unity at the surface of the bay to as much as 1.027 at depths of 300 ft. or more. Typical salinity-temperature-density variations for Port Gardner Bay are shown in Fig. 3.

Concentrated digester liquor (S.S.L.) contains approximately 11 to 12 per cent solids, and has a specific gravity of about 1.05. About 2.5 m.g. of this material, together with other mill wastes, totaling about 20 m.g., are discharged daily through the Port Gardner Bay diffusion line. The resultant mixture has a specific gravity ranging from 1.004 to 1.008 and a temperature range of 30° to 50° C.

It is likely, in consideration of the waste and the water into which it discharges, that any mixture of the waste and the sea-water will have a density always less than the sea water in the immediate vicinity of the outfall line, and frequently greater than that of the surface waters of the bay. Since the differential density is the factor which determines whether the diluted waste rises or remains at the discharge elevation, it may be postulated that the mixture in question rises until a level is reached where its density is equalled by the surrounding water. It then ceases vertical movement and is dispersed throughout the area by tidal currents. This conclusion is substantiated by the survey results previously reported.

The level to which the mixture will ultimately rise depends on many factors; the stage of river runoff, the effect of tides and local currents on dilution, the difference in waste density and temperature, etc. During the course of the 1951 survey the zone of greatest waste concentration was observed to range in elevation from 50 to 200 ft. below the surface of the har-

TABLE VI.—Variations in Dissolved Oxygen with Depth at Four Relatively Unpolluted Locations

Depth (ft.)	Diss. Oxygen (p.p.m.)		Spent Sulfite Liq. (p.p.m.)[1]	
	Av.	Range	Av.	Range
1	8.73	8.25–9.6	tr	tr–14
50	7.33	6.8–8.0	tr	tr
100	6.62	5.7–7.5	tr	0–21
200	5.64	5.0–6.6	tr	tr–18
300	4.90	3.0–5.5	tr	tr–13

[1] tr = trace, or less than 10 p.p.m.

bor. In general, the greatest concentrations were noted at a level of approximately 100 ft. below the water surface.

Of particular significance with relation to the formation of a migration barrier in the Snohomish River is the relatively unpolluted condition of the surface water of Port Gardner Bay as compared with the condition of the water at a depth of 100 ft. Since it is the surface water of the harbor which is carried into the river channel and confined by a flooding tide, any reduction in the pollution load of this water will lessen the probability of creating a migration barrier. That there has been considerable improvement in the quality of surface water in the vicinity of the outfall is particularly evident in a comparison of data collected before and after the installation of the pipeline. In 1949, the average spent sulfite liquor concentration for 30 samples collected from the surface strata (0 to 25 ft.) in the vicinity of the present outfall was 732 p.p.m. Dissolved oxygen concentrations averaged 2.2 p.p.m. In contrast, a similar summary of 22 samples collected in the same area in the 1951 investigation indicated an average S.S.L. concentration of 21 p.p.m. and a D.O. content of 7.7 p.p.m. These observations are substantiated by the survey of conditions at the mouth of the river, as discussed in a prior section of this paper.

Samples taken at more remote stations (Numbers 6, 7, 8, and 9, Figure 1) revealed only slight amounts of spent sulfite liquor and there was no evidence of stratification. However, despite the negligible concentration of S.S.L. present at these locations there was considerable variation in the dissolved oxygen concentration with the depth at which the sample was taken. A summary of the data collected at the four stations is given in Table VI, and also in Figure 4, where it is contrasted with typical observations for two locations near the deep-water disposal line. Average D.O. concentrations were noted to vary from 8.7 p.p.m. at the surface to 4.9 p.p.m. at a depth of 300 ft. for the more distant stations.

Similar gradients in dissolved oxygen content have been observed for natural fresh-water bodies where the

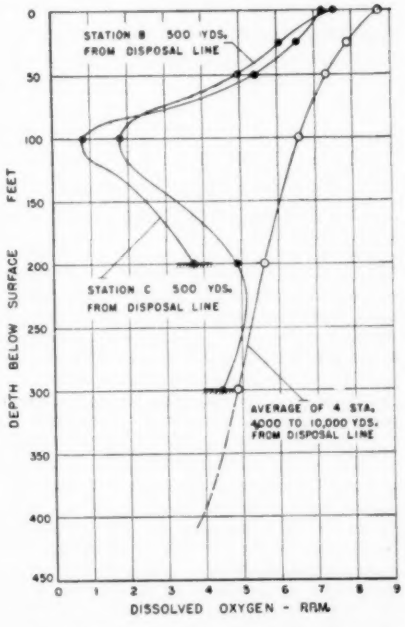


FIGURE 4.—Relation of depth and dissolved oxygen, Port Gardner Bay, June–July, 1951.

only sources of available oxygen are surface reaeration from the atmosphere or photosynthetic oxygenation by chlorophylaceous plants inhabiting the surface strata. Decomposition of organic debris deposited on the bottom creates an oxygen demand and establishes an oxygen gradient from surface to bottom. It is apparent that such a situation may also occur in unpolluted marine waters where the factors contributing to the formation of such a gradient are not greatly different from those for fresh-water lakes. In salt-water bodies greater depths, tidal fluctuations and currents, and salinity variations somewhat complicate the picture, but the principles are much the same as for fresh water.

In the case of Port Gardner Bay the superposition of chemical and biochemical oxygen demands on the natural oxygen deficiencies of the harbor water by the introduction of large volumes of pulp mill waste will no doubt further accentuate the natural dissolved oxygen gradients. Such effects are already evident in the inner harbor, where the accumulation of organic debris produces a significant demand on the oxygen resources of the subsurface water. Much of the harbor bottom in this area is completely devoid of oxygen.

The method of disposal now being used by the pulp mills on Port Gardner Bay appears to have a number of significant advantages over the old method of surface discharge, but it may be a considerable time before the effectiveness of the deep-water dispersal line can be fully evaluated. It does constitute a temporary solution to the immediate problem, that of removing the potential barrier to the normal migration of salmonoid fishes in the Snohomish River, but future surveys will be necessary to determine adequately the long-time effect of deep-water disposal on the waters of the bay.

Reference

1. Eldridge, E. F., and Orlob, G. T., "Investigation of Pollution of Port Gardner Bay and Snohomish River Estuary." THIS JOURNAL, **23**, 6, 782 (June, 1951).

ERRATA SHEET FOR A.C.S. MONOGRAPH 118

The authors of the section on Plating Wastes in the recently published A.C.S. Monograph 118, "Industrial Wastes—Their Treatment and Disposal," have advised that in the editorial work on this section the bibliography was shifted from a consecutive number system to an alphabetical order system. Unfortunately, in making this change a great many errors were introduced, particularly in that the reference numbers in various tables of data were not changed from the original system. Because of the possible resulting confusion, and the peculiar pattern of distribution of the monograph, an errata sheet has been prepared by the authors to endeavor to clear up the situation. Copies of the errata sheet may be obtained by writing to M. G. Burford, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn.

HOME STUDY COURSE ON PLATING WASTES

A new home study course in "Water and Waste Control for the Plating Shop" has been announced. The course is most unusual in that it is being offered by the Joseph B. Kushner Electroplating School, of Stroudsburg, Pa., a private commercial enterprise.

Intended for platers, metal finishing executives, chemists, and engineers dealing with the necessity of curling or abating plating wastes discharges, the course covers the fundamentals of treatment and recovery of plating wastes, wastes reduction methods, treatment economics, reduction of water use, improved plating techniques, and design and operation of waste treatment facilities. Certificates are awarded for successful completion of the three-week home study course, or the text and bibliography can be used as reference material.

GRAVITY SEPARATION OF SILT FROM INDUSTRIAL WASTES *

By C. L. Siebert, Jr.

Chemical Engineer, Pennsylvania Department of Health, Harrisburg, Pa.

Silt is defined as being unconsolidated or loose sedimentary material whose constituent rock particles are less than 1/16 mm. in diameter. The dictionary definition goes further to say that silt may grade into clay, with particles generally less than 1/256 mm. in size. The use of the term "silt" in its consideration as an industrial waste has not been as specific as the dictionary definition in the specified maximum particle size. In dealing with waste products, the top size is limited by the minimum size of particle that can be used as saleable product in the process concerned, and is often considerably larger than the top size of silt according to the dictionary definition. In the case of anthracite coal, for instance, the No. 5 Buckwheat size is commonly dewatered on about 1/32-in. or 28-mesh screens and in most plants the material finer than this is considered waste.

One point inferred in the dictionary definition is that there is no minimum size specified for material classed as silt. This is of particular significance in considering the character of material that must be retained in silt removal works and not discharged to the streams.

Sources of Silt

In Pennsylvania, at least, silt can be considered as coming principally from four main sources. These sources are breakers and washeries preparing coal, quarries and washeries preparing sand and stone, power plants discharging ashes as a waterborne waste, and miscellaneous other mining and metallurgical plants. Although the coal industry could probably be considered in the last classification, in Pennsylvania it is of sufficient magnitude to be considered separately.

The design, construction, and satisfactory operation of facilities retaining silt from nearly all of the coal processing plants in Pennsylvania has already been accomplished; therefore, this phase of silt control is probably of less current interest than those phases in which work still remains to be done. In passing, however, it should be said that the washing of bituminous coal is becoming increasingly more common, and the preparation of bituminous introduces certain problems not found in anthracite practice. Some additional experimental work and particularly the consideration of appropriate requirements, may need to be met separately, but it is believed that the differences between the handling of silt from anthracite and from bituminous preparation are not as large as some people think. This is based upon observations made of silt treatment facilities already in use at a number of bituminous coal preparation plants.

The separation of ashes from power plant waste waters is relatively easy because ashes usually have size and settling characteristics that facilitate ready separation. The separation of the solids from slurries carrying fly ash is probably the most difficult problem in this class, although control of fly ash from large power plants employing

* Presented at 25th Annual Conference Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 26–28, 1953.

suspension burning is now being accomplished.

It appears, therefore, that the principal work still remaining to be done lies in the categories of quarries, sand washeries, and other mining and metallurgical plants. In general, the most troublesome constituent remains the same—namely, natural clays. This remains true in coal preparation, particularly now that surface mining and full-seam deep mining are employed in ever greater proportion.

Reason for Removal

Since most silt is natural material, the question may arise as to why such material should be removed from waste waters, and not allowed to discharge to the streams and rivers. The character of the streams in the anthracite region during the past 50 years is an extreme example of what can happen when unlimited quantities of silt are discharged, quantities so large that deposits 10 ft. deep on the stream bottom were not uncommon. This condition, of course, was caused by the deposition of solids from an entire industry, rather highly concentrated in a particular area. The shoaling in streams of waste silt from other processes is conceivable, and actually has occurred in some relatively large streams from sand washery tailings. Shoaling, then, with its distortion of the normal stream channel and the resultant flooding of lowlands is one reason for requiring retention of silt.

Those particles which are too small to produce shoal deposits, but which remain in suspension and are carried for great distances by the receiving stream can cause degradation of water quality to an objectionable extent in cases where dilution in the receiving stream is not sufficient, or where a downstream water usage requires water of high quality. Such downstream usages would include public water supplies, the use of the stream for bathing purposes, and use for certain manufacturing processes where the presence of suspended solids is objectionable. Of course, such solids can be removed by filtration processes, but this places an additional burden on downstream users.

Extent of Removal

The Pennsylvania Sanitary Water Board has established specific standards for waste treatment for a number of industries, based upon percentage removal from accepted normal raw wastes. Such specific standards have not been adopted with respect to inert solids. There are general requirements, which stipulate the removal of "practically all of the settleable solids" from waste waters discharging into streams on which primary treatment is required, and "practically all of the suspended solids" where discharging into streams on which complete treatment is required. As the term "practically complete" has been applied, to date it has meant generally the removal of about 98 per cent of the quantity present in the raw waste.

In the particular case of coal silt, where the standard of treatment has from the outset been based upon a requirement of 3 hr. actual detention period in settling basins, it was found by actual practice that a flat standard of 1,000 p.p.m. maximum suspended solids could be met by all collieries providing the required treatment, and was a very convenient standard for enforcement purposes. This 1,000-p.p.m. requirement at present applies to all coal washing plants, both anthracite and bituminous, although representatives of some of the large bituminous producers feel that it is perhaps too rigid and wish a more lenient standard, or at least one on a different basis. This feeling is based upon a number of very real differences between anthracite and bituminous preparation practice. However, it is believed that the 1,000-p.p.m. standard can be met by the bituminous

industry without particular hardship. It is at present being met by a number of plants.

It is intended in the near future to collect sufficient data on raw wastes and treated effluents from a variety of sand preparation plants to be able to recommend to the Sanitary Water Board for adoption, if this seems adviseable, of a more specific requirement for quarries and sand washeries. Meanwhile, it is felt that treatment at least to the degree required from coal washeries is justifiable, and to possibly a higher degree when discharge is to streams on which complete treatment of wastes is required.

Methods of Removal

Settling Basins

The simplest and most universally used method of solids removal is by settling ponds or basins. If of sufficient capacity for the quantity of waste water being treated, and large enough to permit accumulation of the solids contained in the waste water, settling ponds can in most cases be operated to produce a sufficiently clear effluent.

Advantages of basins are usually a minimum of investment for the capacity involved, the simplest possible operating practice, and, in some cases, the deposit of the solids at the point of ultimate disposal.

Limitations are the inability of such basins to meet quality requirements in a small space, the possibility of high cost in providing continuing capacity by frequently raising the embankments or by periodically removing accumulated solids in a wet condition, and the generally random mixture of all of the waste solids, some of which may have subsequent value according to their size.

Roughing Tanks

Settling tanks and hydro-classifiers may be used as roughing tanks to reclaim a particular size fraction. Rectangular settling tanks with relatively short detention periods and reasonably fast collector speeds are widely used for this purpose, as are radial flow tanks in which the flow rate is adjusted to make a size cut at the desired point. As generally used, this type of equipment makes a cut at some point larger than 100 mesh.

The use of such units may be desirable where a size fraction has marketable value, or to remove a fraction which can be readily settled and dewatered, thereby reducing the over-all cost of operation where rehandling and hauling is necessary in any event. It has been found by a number of coal operators, even those with quite small plants, that by the installation of a roughing tank ahead of an existing silt pond, not only can the life of the silt basin be prolonged, but there also is a steady source of income for the material removed in the roughing tank, even though the price per ton is small, and the handling cost is much lower than by re-excavation of this material from the silt pond.

About the only point against the use of roughing tanks is that sometimes the presence of larger material in a mixed-size consist will improve over-all settling characteristics by helping to sweep down the extremely fine solids, which otherwise may remain suspended for a long time. Impairment of settling characteristics to a troublesome degree is not usually caused by roughing tanks.

Mechanically-Cleaned Clarifiers

Mechanically-cleaned clarifiers, usually of radial flow type, are used to produce an effluent of higher quality than is obtainable in a roughing tank. There is almost no minimum size to the particles which can be successfully removed in a mechanically-cleaned clarifier, providing the unit is large enough for the particular application. A mechanically-cleaned clarifier will pro-

duce, in limited space, an effluent far better than can be produced by a settling basin in the same limited space. Such units are, of course, expensive. It must not be forgotten that even with a mechanically-cleaned clarifier producing an excellent effluent, there is still the problem of disposal of the underflow from such unit, which must usually still go to a settling basin, although this basin can be much smaller than the basin which might have been required had not a mechanically-cleaned clarifier been provided in the first place. Of course, in figuring storage capacity for the solids that will be accumulated in the underflow basin, the solids that will be accumulated are the same as those contained in the raw waste prior to concentration in the clarifier. Occasionally clarifier underflows are fed to vacuum filters and the use of a settling basin is avoided entirely. This method is practiced at several large bituminous coal preparation plants, where the filter cake is disposed of along with dry mine rock.

Dutch Cyclones

A relatively new unit capable of performing separation of solid particles is the cyclone thickener (1), which is a hydraulic centrifuge designed to produce a maximum practical separation between the water and the solids of a slurry, or to classify the solids according to particle settling rate. So far, these units have been used almost entirely in coal preparation, at least in Pennsylvania, and mostly in bituminous applications. The accomplishments of these small units are quite spectacular. In one washery, four 14-in. diameter thickeners handling 300 g.p.m. removed 22 tons per hour of solids analyzing 5 per cent through 200 mesh and 100 per cent through 14 mesh. When 3-in. units are used, the standard manifold consists of 22 such cones. In another, where the feed to 22 cones was 250 g.p.m. at a pressure of about 40 lb. per square inch, 26 tons per hour of solids were removed, substantially all minus 325 mesh.

Generally speaking, the 3-in. cyclones will remove particles finer than the 14-in. units. The principal application of cyclones is in connection with closed circuit operation (2) (3), where the recirculated process water must be kept below a certain suspended solids concentration in order not to interfere with preparation. In bituminous coal practice, the permissible solids concentration is often fairly high because of the type of hydraulic preparation equipment used. Wider application of these Dutch cyclones may be practical, for as stated earlier, it is the necessity to remove fine clay particles that arises in coal preparation, sand preparation, and in other metallurgical and ore dressing processes.

Of course, the underflow from the cyclone thickeners must be handled in some final unit to dewater the solids and allow the carrying water to be either discharged to a stream or returned to the preparation circuit. A vacuum filter, a suitable screen, or a small slush pond can be used to receive the underflow from the cyclones. In closed or nearly closed coal preparation circuits, the use of dewatering screens or vacuum filters is generally preferred to the use of silt ponds for this purpose.

The application of cyclone clarifiers requires rather exact engineering. One feature which must not be overlooked is the possibility of a build-up to an objectionable extent of solids of a size below that at which the cyclones are making their cut. Several writers have covered cyclone performance in considerable detail.

Closed or Nearly Closed Systems

Recirculation of process water can often be performed to advantage where the quality requirements for process water are less strict than the requirements for an effluent to be discharged

to streams. The adoption in Pennsylvania of substantially closed water systems is likely to increase as the Commonwealth's silt control program is extended to industries other than coal. A possible build-up of fine solids must be taken into account when considering any closed circuit. In many plants a closed system using one combination silt and water supply pond may do the required job with little expense and no installation of mechanical units. At plants using a large quantity of water, closed systems usually must include some form of mechanical clarification equipment.

Comparison of Solids Removal Methods

In order to provide a final effluent treated to a degree suitable for discharge into the streams, either a silt pond or a clarifier is usually necessary. While the various other methods of separation are useful in removing solids, frequently at a high rate, these separations take place under conditions beyond the range of a satisfactorily clarified effluent.

In a particular application, the choice of the unit or units which should be used is often an economic one. In balancing the economy of one particular type of unit or combination thereof against another, the considerations should include the probability of future value of the material being separated, the volume for storage in the location at which the solids will be originally deposited, and the cost of rehandling the separated solids. The cost of rehandling will depend upon the character of the material, especially its dewatering characteristics, and the availability and cost of power shovels, trucks, loaders, and such equipment.

Conclusion

The foregoing has been only a general discussion, and has presented no statistical data nor any cure-all method of separation applicable to all cases. Various separation difficulties may be encountered with certain materials.

Peptized clay particles carry like electrical charges and thereby repel each other, resisting coalescence and flocculation. In such cases chemical treatment may be desirable, although chemical treatment usually should be avoided to keep down operating cost.

Occasionally in a recirculation circuit the build-up of extremely fine solids may become so great that the viscosity of the slurry seriously interferes with settling. Dilution with clear water may be a means of treatment in such cases. Some dilution will take place more or less automatically if the slurry is treated in a silt basin.

In considering the application of a clarifier, the clarification of the overflow is not the only criterion; the tank also must be of sufficient size to hold the expected daily tonnage of underflow during the thickening stages. These are examples of various considerations that may be encountered.

Probably in by far the largest number of cases, a few simple determinations of the quantity and character of solids in the waste waters will go far toward pointing to a solution to the individual problem. Only in the largest installations, where flow rates are great and the difference in cost between separation by one method and another is magnified by the large tonnages involved, is a highly theoretical approach required.

References

1. Driessen, M. G., and Criner, H. E., "Cyclone Thickener." *Mining Eng.*, (Jan., 1950).
2. Kennedy, G. H., and Criner, H. E., "Application of Cyclone Thickeners to Preparation Plant Water Circuits." *Mining Eng.*, (Mar., 1951).
3. Phillips, V., and Blair, J. P., "Cyclone Thickeners, A Practical Solution for Closed Water Circuit Operation." *Mining Eng.*, (Aug., 1951).

TOXICITY OF MERCURIC CHLORIDE, CHROMIC SULFATE, AND SODIUM CHROMATE IN THE DILUTION B.O.D. TEST

A Report of the Research Committee, Subcommittee on Toxicity of Industrial Wastes, Section II

Because of the confusion in the literature concerning the toxic level of many of the common ions such as mercury and chromium that are frequently discharged in industrial wastes, the Research Committee on the Federation felt that it was necessary to obtain a large amount of data concerning the toxic level of these ions. This report includes the data accumulated by some organizations in the various parts of the country. The reason for obtaining data from many different areas was an attempt to get as much variability in the seed and to eliminate any common or constant error in technique such as might occur in one laboratory. It is the present plan of the subcommittee to obtain more data of this sort and to publish the results as this information becomes available.

Methods

In all of the data presented here, the dilution B.O.D. technique has been used. A control B.O.D. was set up and then the control plus a minute amount of the toxic agent was added to other dilution bottles and the B.O.D. was determined after the standard five days. A rather wide range in concentration of mercuric chloride was studied, the lowest concentration being 0.025 p.p.m. and the highest concentration 2 p.p.m. The concentration range for chromium was much higher, beginning at 1 p.p.m. and extending through 10 p.p.m. The study of the toxicity of the chromate required a duplicate set of bottles for the titration of the dissolved oxygen in the presence of the chromate ion which, upon the determination of the dissolved oxygen, liberated iodine giving a much higher value for the dissolved oxygen than would have been obtained in the absence of the chromate. By having a duplicate set of blanks it was possible to determine the depression in the dissolved oxygen by noting the difference between the bottle with chromate and no sewage and the bottle with chromate and sewage.

Results

All of the results of the 58 individual determinations of the toxicity of the mercuric chloride and the 15 determinations of the toxicity of the two types of chromium are summarized in Figure 1. The data for the mercury indicate that there is a slow increase in the toxicity of the mercury from 0.02 p.p.m. to 0.2 p.p.m., and that beyond 0.2 p.p.m. there is a sharp rise in the toxicity of the mercuric chloride until at approximately 2 p.p.m. mercuric chloride there is complete bacteriostasis or the absence of a B.O.D. within the 5-day period. It can be seen that the chromium is much less toxic than the mercury, with the chromic ion being rather more toxic than the chromate ion in the range from 1 to 10 p.p.m. in the dilution B.O.D. test. It may be pointed out, although the significance is not known, that the slope of the line for the lower concentration of the mercuric chloride is similar to that for the slope of the line with the hexavalent chromium and that the slope of

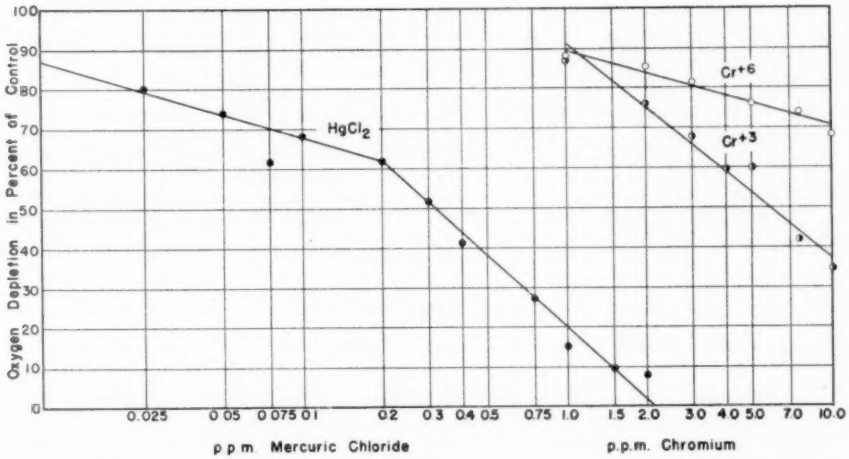


FIGURE 1.—Average values from 58 individual runs comparing the B.O.D. of sewage alone and sewage with various amounts of mercuric chloride, and of 20 runs comparing sewage alone and sewage with various amounts of chromium in the form of chromic sulfate and sodium chromate.

the line with the higher concentrations of the mercuric chloride is similar to the slope of the line for the trivalent chromium.

Discussion

Between the time that the committee collected the data and the preparation of this brief report there have been a number of papers dealing with the toxicity of some of these compounds, but it is the purpose of this discussion to mention only two of them at this time. It should be pointed out that Ingols and Kirkpatrick (1) have shown that the toxicity of chromium is dependent upon the concentration of the organic matter present; that is, upon the level of the potential B.O.D. This can be demonstrated only in a B.O.D. where there is no dilution. This is not true where there is a maximum organic matter concentration of approximately 10 p.p.m., as is typical of all of the studies reported here. Chromium at 20 p.p.m. gives a reduction of only 100 p.p.m., or approximately 10 per cent, where the control has a B.O.D. of 1,000 p.p.m., whereas 20 p.p.m. of chromium gives a very marked reduction in the B.O.D. in a dilution technique. Von Esseltine and Rahn (2) indicate that 50 p.p.m. mercuric chloride at 20° C. is required in an ordinary nutrient broth medium of approximately 5,000 p.p.m. organic matter for bacteriostasis, as opposed to the results of these tests where 2 p.p.m. of mercuric chloride gives complete bacteriostasis with 10 p.p.m. organic matter. Thus, the data of this committee are of importance in understanding the effect of the ions of mercury and chromium in situations such as a polluted stream, but not for situations such as sewage treatment processes.

The mercuric chloride data were obtained by the late Stuart E. Coburn, Metcalf and Eddy, Boston, Mass.; Prof. C. N. Sawyer, Massachusetts Institute of Technology; Wallace W. Sanderson, New York State Board of Health; Prof. G. P. Edwards, New York University; Prof. Willem Rudolfs, Rutgers University; Prof. W. L. Mallman, Michigan State College; and Roy M. Weston, Atlantic Refining Co., Philadelphia, Pa.

The chromium data were obtained by W. L. Krieger and W. A. Moore, USPHS; Prof. C. N. Sawyer, Massachusetts Institute of Technology; Joseph A. McCarthy, Lawrence (Mass.) Experiment Station; and Prof. R. S. Ingols, Georgia Institute of Technology.

The data have been assembled and prepared by Robert S. Ingols, present chairman of Section II, Subcommittee on Industrial Wastes.

References

1. Ingols, R. S., and Kirkpatrick, E. S., "Study of Chromium Toxicity by Several Oxygen Demand Tests." *Anal. Chem.*, **24**, 1881 (1952).
2. Von Esseltine, W. P., and Rahn, O., "The Effect of Temperature upon Bacteriostasis." *Jour. Bact.*, **57**, 547 (1949).

STEEL INDUSTRY POLLUTION ABATEMENT STEPS

In a paper on "Stream Pollution Abatement in West Virginia and the Steel Industry," H. A. Stobbs, Industrial Wastes Engineer, Wheeling Steel Corporation, summarized the reduction of certain steel waste components by good housekeeping, new equipment, and better processing methods. The paper was presented at the 7th Annual Meeting of the West Virginia Sewage and Industrial Wastes Association, held at Morgantown, W. Va., September 2–3, 1953. The following are excerpts from the paper.

At one plant, old-style batch-type steel picklers used 142 per cent of the acid found necessary by the continuous pickler when it was first installed. Modifications of the equipment and practices have reduced acid use to 30 per cent of that originally needed by the continuous pickler. In addition, the spent pickling liquor is overflowed continuously to the sewer, rather than being dumped into the river in tank batches.

In some instances pickling has been dispensed with entirely through controlled-atmosphere annealing. In other cases, oxide removal is not required, also obviating the necessity for pickling.

Flue dust recovery at one plant amounts to 98.8 per cent of the 59.76 tons produced per day. Processing of the dust to recover iron values helps to offset the cost of this operation.

Approximately 1 ton of coke is required to make 1 ton of pig iron. Recovery of by-products from the coking operation has reduced by 80 per cent the wastes formerly discharged to the stream per ton of coal coked, including reduction from 6,300 lb. to 500 lb. per day of phenols. Other items recovered include zylene, toluene, benzene, ammonium sulfate, and pyridine. The latter (about 2,000 gal. per month) yields a modest profit.

Mechanical equipment improvements have reduced lubricant losses considerably, lubricant use being only 53 per cent of what it was 10 years ago. Standardization of lubricants also has helped, not only to reduce the number of types required, but also to permit automatic lubrication from central units.

Stream Pollution

FUNGI IN POLLUTED WATER AND SEWAGE

I. Literature Review

By Wm. Bridge Cooke

Mycologist, Bacteriology Section, USPHS Environmental Health Center, Cincinnati, Ohio

In developing a program for the study of the fungi associated with polluted water and sewage treatment, it was necessary to review the work of earlier students of the biology of such habitats. *Sphaerotilus* and other bacteria are included because in the past they have been considered "sewage fungi" and they are still referred to in this way.

In the text books dealing with the microbiology of water, such as Ward and Whipple (34), Lackey in Phelps (15), and recent bacteriology texts in which pollution is treated, fungi are either ignored or given only brief passing mention as organisms which may be part of the normal microbiota of such habitats. Whipple (37) indicated what groups of fungi could be found, gave the ecological classification of certain reported species of filamentous bacteria and molds according to the Kolkwitz and Marsson system, and illustrated several of the more common species.

Kolkwitz (13) (14) presented the first work done on the biology of *Leptomitus lacteus*, especially in relation to its habitat requirements in polluted water and its cultural characteristics.

Shortly after installation at Waterbury, Conn., of several filters 7 ft. in diameter and 5 ft. deep in which stone 1¾ to 2¼ inches in diameter was used, growth appeared which caused ponding. These were studied by Rettger (21). The growths on the filter were red to black in color, although when washed they became white to reddish. They were obviously molds and when streaked on gelatin, after washing away most of the bacteria, mold colonies developed. From the description and drawings the mold was undoubtedly *Geotrichum candidum*. Rather than being caused by iron, as the author supposed, the red color may have been due to the presence of *Fusarium aquaeductuum*, which did not appear in the plating. The growth was controlled by resting the filter, turning the stone, and hosing, or simply by resting the filters for a day or two, after which the dried flakes of growth washed off when the sprays were turned on.

Wilson and Calvert (39) suggest that growths in streams can be used as indicators of pollution. Specific examples are given, such as the discharge of spent gas liquor, which caused *Botrytis vulgaris* to produce growths which blocked the channel of a small stream, and which in other places aided the growth of masses of *Sphaerotilus natans*, *Beggiatoa alba*, and *Oospora* or *Fusarium solani*. Bleach-croft refuse caused large developments of *Sphaerotilus natans* and brewery effluents favored the growth of *Monilia variabilis*.

Weston and Turner (35) found in

the Coweeset stream, a tributary of the Taunton River which received the effluent of the sewage treatment plant of Brockton, Mass., a large amount of *Leptomitus* which supported various types of life and which was supported by other types. It was found that certain organisms present in the stream assisted in maintaining an environment favorable to the development of *Leptomitus*. When warmer temperatures occurred these organisms were inhibited and others became more abundant. The latter organisms appeared to produce conditions in the stream inhibitory to *Leptomitus*. *Leptomitus* developed profusely below the effluent drains, but never in the stream into which the Coweeset drained.

Tiegs (30) presented brief notes on the biology of *Leptomitus*, *Sphaerotilus natans*, and a new species of *Penicillium*, *P. fluitans*, isolated from industrial wastes. This species of *Penicillium* has recently been evaluated by Raper and Thom (19) as a member of the *P. frequentans* series characterized by its ability to exist in solutions of 0.25N nitric acid.

Previous scattered literature reports of fungi in sewage plants were summarized by Cox (6). He reported that Dunbar (7) indicated that *Peziza omphalodes* and *Pilobolus oedipus* were present on filters, as well as in upper scums of septic tanks. In practically all cases the growths were considered of no value to good treatment and several types of removal techniques were recommended, such as flushing, resting the filters, or chemical control. In all cases observed, growth occurred in fall, winter, or spring months. Cox studied the organisms on the filters at the Back River plant, Baltimore, Md. Among the organisms found were two unidentified fungi and the usual *Zoogloea*, *Sphaerotilus* (*Crenothrix*), and *Beggiatoa*. From his descriptions the pink fungus was probably *Fusarium aquaeductuum* and the grey mold *Geotrichum candidum*. Cox's work is largely of historic interest.

Haensler, Moore, and Gaines (8) studied a vertical spray type trickling filter plant at Plainfield, N. J., and found several fungi, of which five were chosen for special study. They studied materials from the surface and from 1-, 3-, and 5-ft. depths in the filters. Material found was classified in five categories according to the texture of the mat. Subsurface and surface findings were tabulated according to the period of time in which collections were made. *Penicillium* sp. was more common in late summer, fall, and winter at 1 ft.; *Oidium* sp. appeared more commonly in the first foot in the winter; unidentified fungus No. 3 (similar to the *Sepedonium* of the English workers) was a mid-spring fungus of the upper foot; *Pythium* sp. No. 4 appeared in the third foot more commonly, especially in the late winter and early spring; the fungus called *Dictyuchus* No. 5 occurred in winter and spring about equally abundantly at all depths. It was concluded that fungi were important in building up and binding the surface film of the stone in the filters.

Rudolfs and Trajkovich (26) continued studies on the distribution of fungi in filter beds. They found that the fungi they studied increased in abundance as the temperature of the Imhoff tank effluent decreased during the year.

The same workers studied a species of *Penicillium* found on the filters. The culture was aerobic, used organic rather than inorganic nitrogen, did not produce ammonia, and was unable to decompose cellulose or to liquefy gelatin.

Starting as a study on the food of the insect *Achorutes viaticus*, the fungi of slimes of trickling filters and of a public-house cellar were studied by Bell (2) in England. Slimes were placed in a 1:100,000 solution of formaldehyde for 96 hr. and molds isolated in

pure culture from them. In the Barnsley filter slime were found *Torula rosea, Mucor mucedo, Oidium lactis,* and *Penicillium* sp., whereas in the public-house cellar at Ripon, Yorkshire, were found *Torula rosea, Mucor rouxii, Oidium lactis,* and *Penicillium glaucuum.* On the basis of a demonstration that the insect fed on these molds, it was sent to nearly 40 sewage installations on three continents as a means of keeping the mold population under control.

One of the earliest reports of sewer line trouble resulting from mold growth in North America was that of Hall (9), who reported that *Sphaerotilus natans* and *Leptomitus lacteus* caused serious trouble within a block or two of a creamery in Choteau, Mont. The trouble was apparently cleared up by the use of copper sulfate and continued periodic scrubbing to break up the film of growth.

In a primary treatment plant at Atlantic City, N. J. solids were settled out of sewage in tanks and pumped to drying beds. As soon as the sludge could be handled easily it was removed to vacant lots or under sheds. After further drying it was stored in darkened buildings where molds were encouraged to grow. It was not indicated which molds were present or whether the material with its microbial populations, which must have included bacteria, was sterilized before its sale as "fertilizer." Wigley (38) indicated that this process was patented.

Prior to 1932 several species of filamentous bacteria and fungi had been reported in the taxonomic literature as having been obtained from polluted waters and sewage systems as well as, in some cases, clean water mains. Information on these was brought together by Butcher (4), who, working in England, was especially interested in polysaprobic organisms. Under the term "sewage fungus" he grouped several species of filamentous and zoogloeal bacteria, fungi, and stalked, ciliated protozoans. These were well-known components of the microbiota of polluted habitats. The species he treated deserve special consideration here because they are mentioned most prominently throughout the literature of pollution organisms whenever filamentous bacteria and fungi are discussed.

Filamentous Bacteria

Sphaerotilus natans Kützing, and its varieties listed below, according to Butcher occurred where growth was very rapid. *S. natans* var. *natans,* itself, is characterized by the presence of a gelatinous sheath around each filament. *S. natans* var. *vulgaris* Butcher has filaments which are found in a common gelatinous matrix and occurs as plumose or tassel-like growths 1 to 10 cm. long in free-running water. *S. natans* var. *prolifera* Butcher resembles Zopf's idea of *Crenothrix polyspora.* It occurs with the preceding forms, to the second of which it is similar. *S. natans* var. *cladothrix* Butcher (*Cladothrix dichotoma* Cohn) is characterized by the type of false branching of the filaments which has led many workers to include it in a separate genus. It occurs in habitats similar to those of the preceding varieties. *S. natans* var. *depauperatus* Butcher appears to be a dwarfed form in response to a diminishing supply of nutrients characteristic of the cleaner portions of streams downstream from sources of pollution. *S. natans* var. *transiens* Butcher seems to be another form resulting from suboptimal environmental conditions, producing a growth form intermediate between *Sphaerotilus natans* and *Zoogloea ramigera.*

Zoogloea ramigera Itzigsöhn forms spherical, branched, or lobed colonies and is well-known to sewage treatment plant operators. Whether or not it is a species which can be retained in good standing, or merely one stage in the life cycle of several species, is still an unsettled question, according to Butcher.

Beggiatoa alba (Vauch.) Trevis is a bacterium commonly found in sulfur-rich habitats, but which also occurs in the sewage-fungus community where the substratum is rich in organic matter.

Fungi

Leptomitus lacteus Agardh is a water mold with white or colorless hyphae without septa but with constrictions and branches. It forms tufts similar to those of *Sphaerotilus natans*, but is not slimy.

Fusarium aquaeductuum (Radl. and Rabh.) Sacc. is reported as being rather rare, occurring in more acid waters. It has a septate, branched mycelium which produces typical crescent-shaped spores.

Protozoa

Carchesium spectabile Ehrenb. and *C. lachmanni* Clap. and Lach. are stalked, branched, colonial *Vorticella*-like ciliates which form colonies similar to those of *Sphaerotilus* and are thus included in the sewage-fungus community.

Butcher reports that pure culture studies have shown that all these organisms show a preference for nitrogenous compounds either in simple form or as more complex amino acids or proteins. Where the more complex materials have been removed from the stream by degradation, growth becomes less obvious, but when carbohydrates are added to the stream, as in the case of sugar beet mill wastes, growth becomes more abundant. Growth is more dependent on nutrients than on temperature, although the blanket of sewage-fungus growth will extend farther downstream in winter than in summer. *Sphaerotilus* is more prevalent in England, whereas *Leptomitus* appears to a greater extent in continental Europe, a fact which may be explained by the greater dilution of organic wastes in the larger streams of the continent rather than by the state of decomposition of this material.

Working with the bulking of activated sludge, Smit (29) found four organisms to be associated with the process. *Sphaerotilus natans* appeared to be most important, although its identification was unsatisfactory, while *Cladothrix dichotoma* and a *Leptomitus*-like organism seemed to be involved and *"Geotrichoides paludosus"* was associated with the sludge.

Under the chapter heading "Sewage Fungus," Butcher, *et al.* (5) described the local and seasonal distribution of *Sphaerotilus natans* in the Tees and Skerne Rivers of northern England. To get a quantitative idea of this growth, weights of growth on glass slides exposed for 14 days throughout a year's period were recorded. The bacteria *Beggiatoa* and *Zoogloea* were recorded, but no true fungi were listed.

Tiegs (31) brought together the pollution fungi of Germany under the general designation of "Abwasserpilze." The group was similar to the "sewage-fungus" community of Butcher and was treated from the standpoint of required nutrients. By way of introduction it was stated that in the mid-nineteenth century even the layman had little difficulty in observing such growths, as indicated by works of the poet Wilhelm Raahe. The bacteria considered by Tiegs included *Sphaerotilus natans, Zoogloea ramigera, Beggiatoa alba,* and *Thiothrix nivea,* while the fungi included *Fusarium aquaeductuum, Leptomitus lacteus,* and *Mucor racemosus. Beggiatoa* and *Thiothrix* are aerobic sulfur bacteria and were found in such habitats as municipal sewage plants, places where there is a predominance of sulfur, and in industrial wastes from plants in which sulfur is an important part of the process. *Sphaerotilus* did not occur to any extent in such places. These three groups prefer warmer temperatures than other bacteria in these habitats. *Sphaerotilus* prefers cooler temperatures, simple carbohydrates, and more complex nitrogen compounds, such as

amino acids or their degradation products (ammonia or nitrates). It is less sensitive in nature to pH changes than in pure culture.

Leptomitus is the most important fungus in polluted habitats. It prefers nitrogen in proteinaceous form and occurs in either natural or artificially polluted waters. It appears to prefer streams in which the waste from slaughterhouses, breweries, or sugar factories is emptied. These streams often carry up to 200 p.p.m. organic matter. It prefers a cool temperature and a lower pH. It appears that *Sphaerotilus* is less specialized than *Leptomitus* as to its nutrient requirements.

Fusarium aquaeductuum is found in streams below the point of introduction of weakly acid materials. It contains carotinoid pigments, grows in light, and forms a red color on the substratum. The widely spread *Mucor racemosus* is common in sewage effluents rich in organic matter. It preferred colder temperatures, a slightly alkaline pH, and was usually found only when using isolation technique.

Tiegs suggested that rather than treating sewage and industrial wastes with chemicals to prevent the growth of these organisms, the best method was to use settling basins or irrigated sewage fields. In further studies of these organisms it was not only necessary to know their nutrient requirements, but also something more of their environmental conditions.

Blöchliger and Husmann (3), working with the problem of cleaning up the Limmat River, which received the sewage from the city of Zurich, Switzerland, tried three approaches after mechanically settling the sewage. Before treatment of the sewage was started the river bed and banks were coated with a thick blanket of white or gray material resulting from the growth of *Sphaerotilus natans, Leptomitus lacteus,* and *Mucor.* When an 80-m. long test channel was used several zones of growth developed in it, representing those organisms which could survive in the conditions of the material as it passed by. Zones of mold growth near the influent were followed by zones of several types of algal growth. Conditions of the habitat were tabulated and the various species of bacteria, fungi, and algae present were listed. To increase the effectivity of the trough in clearing the mechanically settled sewage, high-rate filtration provided partial purification and an activated sludge plant provided full biologic purification.

Lackey and Wattie (17), in a recent treatment of the biology of *Sphaerotilus natans,* summarized previous work and presented studies on this organism in relation to bulking of activated sludge. They found that five different species of *Sphaerotilus,* possibly only physiological variants of one species, had been associated by various workers with pollution of one sort or another and with sludges in sewage treatment plants and experiments. The activity of this species as a bulking sludge producer in the laboratory was greatest in the presence of excesses of mono- and di-saccharides when an available nitrogen source was present. Using a large number of nutritional variants in activated sludge, sterile raw sewage, medium "L", and synthetic sewage, an attempt was made to determine whether or not additional nutrients were present in sewage which would produce such large growths. No substances other than mono- or disaccharides produced heavy growth of the organism. An attempt was made to find a substance to control the growth of *Sphaerotilus,* especially when it was responsible for bulking of sludge, and not inhibit other members of the sewage-fungus community. It was found that the dye malachite green was inhibitory to *Sphaerotilus.* If this was too expensive for general use some form of chlorination of returned

sludge would be best for most treatment plants.

Schade (27) and Schade and Thiman (28) presented thorough studies of the nutrition and metabolism of *Leptomitus lacteus*. Using modern physiologic and biochemical techniques, their work has brought up to date the work of Kolkwitz and Trommsdorf on this organism and gives the reader an insight into some of the reasons why this organism prefers the more polluted habitats in which it is found.

In a brief text on sewage treatment, Rudolfs (24) summarized the work done on molds in sewage at Rutgers University.

Tomlinson (32) found that the stone of trickling filters was covered with a film of organisms including algae, fungi, and bacteria. This film could, under certain circumstances, form a blanket between stones. The fungi in the Minworth, England, filters included species in the genera *Fusarium*, *Phoma*, *Sepedonium*, and *Oospora*. The film varied in composition and thickness from one observation period to another. *Fusarium* formed tightly adhering mats on the stones and *Phoma* occurred with it, whereas *Sepedonium* and *Oospora* formed continuous mats which caused ponding when mats were of large size. A pair of filters was operated in series experimentally. A 3- to 4-day alternation of filters in the series was used. A series of glass slides was exposed on the surface of these filters and periodically weighed to determine the effect of alternation on the material growing on the filters. A set of slides exposed on a single filter not receiving effluent from another filter showed a gradual increase of film on the slides for several months, then a leveling off, accompanied by fluctuations due to causes found in single-filter operation. The slides on the pairs of filters in series, on the other hand, showed an additional periodic fluctuation as the filter received first the settled sewage, then the settled effluent from the other filter.

Sphaerotilus natans was shown by Ruchhoft and Kachmar (23) to be an obligated aerobe with considerable variability in viability and metabolism. Experimentally, bulking was shown to be a response of sludge organisms to a sudden disturbance in the biological equilibrium, especially as to three primary factors including sludge, nutrients, and rate of oxygen supply. It was found that in certain cases of bulking the disturbance producing it was accompanied by a great increase in *Sphaerotilus*, although other organisms present in activated sludge could cause bulking under other disturbed conditions.

Weston (36) discussed the role of aquatic fungi in hydrobiology. He dealt almost exclusively with those fungi which occur in non-polluted water or water polluted only with dead or discarded remains of tissues of plants growing in the immediate environment of the streams, ponds, or lakes under study. In such places many kinds of fungi live as saprobic invaders of dead tissues, or parasites on plant or animal plankton species, or predators on planktonic species.

Rudolfs and Heukelekian (25) discussed briefly the microbiology of sewage and sewage treatment plants. They mentioned the role of various types of microorganisms in hydrogen sulfide production, sludge digestion, slow sand filtration, trickling filters, and the activated sludge process. Fungi were mentioned as playing a part in the film formation on the stone of trickling filters.

Reynoldson (22) found that in a double filtration plant at Huddersfield, England, there was a correlation between growth of the mold *Oospora* and the fly *Psychoda*, which followed a temperature pattern. In the primary filter there was heavy fungal growth with ponding and sludge accumulation, but with a lowered fly production. In the

coarse secondary filter there was no ponding, the thickness of the fungus blanket was greatest in winter and spring, and the flies followed a normal pattern with temperature, except for a late summer period when they were reduced, apparently by lack of food.

Heukelekian (12) used baker's yeast in seeding open and closed vessels containing ripe sludge to determine the effect of yeast on stimulating digestion and stabilization of sludge. Tests were run at 20° C. and daily observations were made. When 2 g. of yeast per liter of sewage were added in open vessels, the 5-day B.O.D. increased slightly, although it decreased by one-third in uninoculated controls. In a second test, using closed vessels, 0.1 g. of yeast per liter of sewage was used and at the end of 48 hr. the 5-day B.O.D. was slightly higher in inoculated vessels than in uninoculated controls. It was concluded on the basis of 5-day B.O.D. measurements, reduction of volatile matter, and gas production, that yeast does not aid in the stabilization of sewage kept under either aerobic or anaerobic conditions, and that its addition to a new digester would have little, if any, value.

Wilson (41) presented data to indicate the relative importance of the binding organisms, *Beggiatoa alba*, and fungi as a group, and various free-living and scouring organisms in the Glenwood City, Wis., and the Owatonna, Minn., trickling filters.

Lackey and Dixon (16) analyzed the populations of 11 contact aerator plants of the Hays process type. Seventy-one distinct groups of organisms were recognized, but the fungi found were left unidentified. These were found usually in the manner of the plankton specialist studying samples in the Sedgwick-Rafter cell.

Tomlinson (33) studied filters at Minworth in which the three components of the film were a zoogloeal bacterium, *Ascoidea rubescens*, and *Sepedonium* sp. During the summer the film developed to twice the extent of that in the winter because of the greater amount of growth of *Ascoidea* and the bacterium. The *Sepedonium* developed in the winter. On the basis of total dry weight of the film in the top 2 ft. of the filters, a greater amount was found in the single than in the double filters.

Wilson (40) described the conditions under which the microbiota of sewage treatment plants live. In so doing he emphasized three terms: binding, free-living, and scouring, which applied to the habit of the various types of life in the filters. It can be noted that of these categories the fungi of filters fit into the first. In many filters fungi may be the most important binding organisms, whereas the filter fly larvae, as scouring organisms, remove the fungus mycelium and other parts of the film for food. In his analyses of the various habitats Wilson indicates that certain unidentified species of fungi existed.

Beardsley (1) made an attempt to control slimes in the sewer system of Los Angeles, Calif., shown by Pomeroy and Bowlus (18) to cause excess production of sulfides. The occurrence of slimes on walls of sewers was diverse and their effect was variable with respect to time and place. It was found that certain types of organisms were suppressed by chemical treatment while others were unaffected. Organisms responsible were thought to include *Leptomitus lacteus* and possibly *Apodachlya brachynema*, as well as the bacteria *Zoogloea ramigera* and *Beggiatoa alba*. It was suggested that possibly certain Myxomycetes were also involved.

Harvey (10) found 21 species of aquatic fungi associated with streams of the Little Miami River basin. Of these, one occurred frequently enough to be considered a possible inhabitant of the septic zone of Lytle Creek, the stream receiving the effluent of the Wilmington, Ohio, sewage treatment plant.

The reports of the (British) Water Pollution Research Board (20) for 1950, 1951, and 1952 presented information concerning the growth and physiology of fungi of small trickling filters. Where the filter medium was only ¾ in. to 1½ in. in diameter, more ponding, due to fungi, occurred than in the medium which was 1½ in. to 3 in. in diameter. It was also shown that where the filters were operated at 800 and 1,000 g.p.d. per cubic yard only 13 to 14 per cent of the film was fungus mycelium, whereas in filters operated at 200 to 600 g.p.d. per cubic yard this material varied between 14.5 and 30 per cent.

Because of the importance of at least 10 species of fungi in producing ponding effects in the upper layers of small filters, experiments on nutrition of the more important species were undertaken. A species of each of *Sepedonium, Oospora, Sporotrichum,* and *Fusarium aquaeductuum* was selected for special study in 1951. Basic media, pH ranges, mineral requirements, and vitamin nutrition were studied. It was found that *Sepedonium* could grow in a pH range of 4 to 9.5, with optimum of 7 to 8. *Fusarium* and *Oospora* required no outside source of vitamins, whereas *Sporotrichium* required thiamine, and *Sepedonium* required biotin in addition to thiamine. It was found that these vitamins and certain trace elements were present in sewage. *Sepedonium* required oxygen, since it grew well in aerated culture, poorly in quiescent liquid cultures, and hardly at all when nitrogen gas containing 1.2 per cent oxygen by volume was passed over the surface of the medium. In an artificial filter using glass balls and an artificial sewage-like nutrient medium, the filter was found to be effective only after large growths of the fungus had developed after at least 15 days.

In a glucose-casein hydrolysate-mineral salt medium it was found, in 1952 studies, that *Fusarium aquaeductuum* and *Sporotrichum* had a pH range of 3 to 10, with optimum growth at pH 4 to 9. *Oospora fragrans* had the same range, with optimum at pH 3 and no growth at pH 2; *Sepedonium* had the narrow optimum range of pH 7 to 8. The weight of *Sepedonium* after 10 days was found to be directly related to oxygen supply over the range of 2 to 15 per cent of the gas mixture. Nitrogen requirement studies indicated that although *Sepedonium* preferred complex organic nitrogen compounds, *Sepedonium* and *Ascoidea rubescens* required organic nitrogen, *Oospora fragrans* and *Sporotrichum* could use ammonium salts in addition, and *Fusarium aquaeductuum* could also use nitrates. Further studies on minor elements indicated a need for, or tolerance of, 11 elements. Zinc and calcium by themselves were toxic to *Sepedonium,* while in combination with the other 9 elements used, they gave increased yields. Using the optimum mineral salts solution, results of the vitamin experiments reported previously were confirmed. Using settled sewage, *Sepedonium* gave better growth than the use of ashed sewage, which may be explained either as the better availability of growth-promoting substances or of trace elements.

Hesseltine (11) surveyed the surface stone of a trickling filter handling the industrial waste from a chemical laboratory and an antibiotic plant at Pearl River, N. Y. He found three fungi of importance and described them morphologically. These included *Geotrichum candidum, Fusarium aquaeductuum,* and a representative of a new genus, *Subbaromyces splendens.*

The more important species reported by various workers in the period 1901–1953 are summarized in Table I. The liberty has been taken of identifying species where these are recognizably described in the literature but treated as unknowns. Certain names are brought into conformity with recent

TABLE I.—Important Fungi Associated with Sewage and Polluted Waters

Location	Observer	Year	*Leptomitus lacteus*	*Geotrichum candidum*	*Sepedonium* sp.	*Fusarium aquaeductuum*	*Penicillium* spp.	*Sphaerotilus natans*	*Beggiatoa alba*	*Zoogloea ramigera*
Germany	Kolkwitz	1901	x	—	—	—	—	—	—	—
Connecticut	Rettger	1906	—	x	—	x	—	—	—	—
Germany	Tiegs	1919	x	—	—	—	x	x	—	—
Massachusetts	Weston	1917	x	—	—	—	—	—	—	—
Maryland	Cox	1921	—	x	—	x	—	x	x	x
New Jersey	Haensler	1927	—	x	x	—	x	—	—	—
England	Bell	1926	—	x	—	—	x	—	—	—
Montana	Hall	1927	x	—	—	—	—	x	—	—
England	Butcher	1932	x	—	—	x	—	x	x	x
Germany	Tiegs	1939	x	—	—	x	—	x	x	x
Switzerland	Blöchliger	1939	x	—	—	—	—	x	—	—
England	Tomlinson	1941–6	—	x	x	x	—	—	—	—
England	Research Board	1951	—	x	x	x	—	—	—	—
New York	Hesseltine	1953	—	x	—	x	—	—	—	—

ideas of nomenclature. Although the list is incomplete, it indicates that the species of filamentous bacteria and fungi associated with polluted water and sewage are very wide-spread.

From this literature survey concerning fungi of pollution habitats it appears that the workers who have made these studies have done so with materials which have appeared obvious to the field collector. No attempts, or only very cursory attempts, have been made to find those fungi not so easily seen. Fungus mycelia are very similar from species to species either in the group of Phycomycetes, where septation occurs rarely, or in the Ascomycetes and Fungi Imperfecti, where the mycelia are commonly septate or "segmented." Species cannot be separated on this character and must be cultivated to the extent that they will produce reproductive structures and spores by means of which they can be identified. In doing this, different media and techniques are required and several species may become evident where only one appeared before. In preliminary samplings at several sewage treatment plants of two types it has been found that more than 50 species of fungi are associated with such habitats, either as permanent residents or as casual transients. More than 100 species of molds have been found in a stream subject to pollution from the effluent of a sewage treatment plant of the primary type. The problem of the activity of fungi in polluted habitats is not that of discovering the activity of one or of five molds, but of determining the activity of a great many molds, each of which has a different set of requirements, but many of which are more or less physiologically related.

References

1. Beardsley, C. W., "Suppression of Sewer Slimes." *Sewage Works Jour.*, **21**, 1, 1 (Jan., 1949).
2. Bell, H. D., "Research on the Composition of the Grey Slimy Growth on the Surface of Sewage Filters." *Surveyor*, **70**, 561 (1926).
3. Blöchliger, G., and Husmann, W., "Beitrag Zur Kenntnis der Wachstumsbedingungen von Abwasserpilzer in Fliessenden Gewässern." *Zeits. für Hydrologie*, **8**, 55 (1939).
4. Butcher, R. W., "Contributions to Our Knowledge of the Ecology of Sewage Fungus." *Trans. Brit. Myc. Soc.*, **17**, 112 (1932).
5. Butcher, R. W., Longwell, J., and Pentelow, F. T. K., "Survey of the River Tees. Part III. The Non-Tidal Reaches—Chemical and Biological." (British) Water Poll. Res. Board Tech. Paper 6, p. 110 (1937).
6. Cox, R. R., "Non-Bacterial Populations of Sewage Trickling Filters." *Eng. News-Rec.*, **87**, 720 (1921).
7. Dunbar, ——., "Principles of Sewage Treatment." Translated by H. T. Calvert. Chas. Griffin & Co., Ltd., London (1908).

8. Haensler, C. M., Moore, W. D., and Gaines, J. G., In Rudolfs, W., "Studies on the Biology of Sewage Disposal." *N. J. Agr. Exp. Sta. Bull.*, **390**, 1 (1923).
9. Hall, J. W., "Fungus Growth in Sanitary Sewers." *Water Works*, **66**, 177 (1927).
10. Harvey, J. V., "Relationship of Aquatic Fungi to Water Pollution." THIS JOURNAL, **24**, 9, 1159 (Sept., 1952).
11. Hesseltine, C. W., "Study of Trickling Filter Fungi." In press (1953).
12. Heukelekian, H., "Effect of Yeast on the Stabilization of Sewage and Sludge Digestion." *Pub. Works*, **73**, 9, 17 (1942).
13. Kolkwitz, R., "Zur Biologie von *Leptomitus lacteus*." Ber. Deutsch. Bot. Ges., **19**, 288 (1901).
14. Kolkwitz, R., "Über Bau und Leben des Abwasserpilzes *Leptomitus lacteus*." *Ber. Deutsch. Bot. Ges.*, **21**, 147 (1903).
15. Lackey, J. B., in Phelps, E. B., "Stream Sanitation." John Wiley & Sons, New York, N. Y. (1944).
16. Lackey, J. B., and Dixon, R. M., "Some Biological Aspects of the Hays Process of Sewage Treatment." *Sewage Works Jour.*, **15**, 6, 1139 (Nov., 1943).
17. Lackey, J. B., and Wattie, E., "Studies of Sewage Purification, XIII. The Biology of *Sphaerotilus natans* Kutzing in Relation to Bulking of Activated Sludge." *Pub. Health Rep.*, **55**, 975 (1940).
18. Pomeroy, R., and Bowlus, F. D., "Progress Report on Sulfide Control Research." *Sewage Works Jour.*, **18**, 4, 597 (July, 1946).
19. Raper, K. B., and Thom, C., "A Manual of the Penicillia." Williams and Wilkins Co., Baltimore, Md. (1949).
20. Reports, Water Pollution Research Board (British): "Biological Filtration of Sewage." Pp. 7–9 (1951); "Factors Controlling the Growth of Fungi in Percolating Filters." Pp. 14–16 (1952); and pp. 26–28 (1953).
21. Rettger, L. F., "Fungus Growth on Experimental Percolating Sewage Filters at Waterbury, Conn." *Eng. News*, **61**, 459 (1906).
22. Reynoldson, T. B., "Further Studies on the Biology of a Double Filtration Plant at Huddersfield." *Proc. Inst. Sew. Purif.*, p. 1 (1942).
23. Ruchhoft, C. C., and Kachmar, J. F., "Studies of Sewage Purification. XIV. The Role of *Sphaerotilus natans* in Activated Sludge Bulking." *Pub. Health Rep.*, **56**, 1727 (1941).
24. Rudolfs, W., "Principles of Sewage Treatment." Bull. 212, National Lime Assn., Washington, D. C. (1941).
25. Rudolfs, W., and Heukelekian, H., "The Microbiology of Sewage and Sewage Treatment." In "A Symposium on Hydrobiology." Univ. of Wisconsin Press, pp. 273–279 (1941).
26. Rudolfs, W., and Trajkovich, H. A., "Fungi and Algae of the Sprinkling Filter Bed and Their Distribution and Experiments on the Physiology of Fungus No. 2 (*Penicillium*)." 3rd Ann. Rep., Sewage Substation, N. J. Agr. Exp. Sta. Bull. 403, pp. 1–95 (1924).
27. Schade, A. L., "The Nutrition of *Leptomitus*." *Amer. Jour. Bot.*, **27**, 376 (1940).
28. Schade, A. L., and Thimann, K. V., "The Metabolism of the Water-Mold, *Leptomitus lacteus*." *Amer. Jour. Bot.*, **27**, 659 (1940).
29. Smit, J., "Bulking of Activated Sludge. II. On the Causative Organisms." *Sewage Works Jour.*, **6**, 6, 1041 (Nov., 1934).
30. Tiegs, E., "Beiträge zur Oekologie der Wasserpilze." *Ber. Deutsch. Bot. Ges.*, **37**, 496 (1919).
31. Tiegs, E., "Abwasserpilze und Wasserbeschaffenheit." *Vom Wasser*, **13**, 78 (1939).
32. Tomlinson, T. G., "The Treatment of Settled Sewage in Percolating Filters in Series with Periodic Change in the Order of the Filters. II. Biological Investigations." *Jour. and Proc. Inst. Sew. Purif.*, p. 27 (1941).
33. Tomlinson, T. G., "Growth and Distribution of Film in Percolating Filters Treating Sewage by Single and Alternating Double Filtration." *Jour. and Proc. Inst. Sew. Purif.*, p. 1 (1946).
34. Ward, H. B., and Whipple, G. C., "Fresh Water Biology." John Wiley & Sons Co., New York, N. Y. (1918).
35. Weston, R. S., and Turner, C. E., "Studies on the Digestion of a Sewage-Filter Effluent by a Small and Otherwise Unpolluted Stream." Contr. Sanitary Res. Lab., Mass. Inst. Tech., 10, p. 1 (1917).
36. Weston, W. H., "The Role of the Aquatic Fungi in Hydrobiology." In "A Symposium on Hydrobiology." Univ. of Wisconsin Press, pp. 129–151 (1941).
37. Whipple, G. C., "The Microscopy of Drinking Water." 4th Ed., John Wiley & Sons Co., New York, N. Y. (1927).
38. Wigley, C. G., "Molds Utilized to Make

Sewage Sludge Inodorous." *Pub. Works*, **61**, 5, 38 (1930).
39. Wilson, H. M., and Calvert, H. T., "A Text-Book on Trade Waste Waters." Charles Griffin & Co., Ltd., London (1913).
40. Wilson, J. N., "Microbiota of Sewage Treatment Plants and Polluted Streams." In "Limnological Aspects of Water Supply and Water Disposal." Amer. Assn. for Advancement of Science, Washington, D. C. (1949).
41. Wilson, J. N., in Walton, G., "High Daily Rate Trickling Filter Performance: Biological Investigations." Board of State Health Commissioners, Upper Mississippi River Basin Sanitation Agreement. Pp. 113–135 (Mar., 1943).

USPHS SANITARY ENGINEERING CENTER OCCUPIES NEW CINCINNATI QUARTERS

The new $4,000,000 building in Cincinnati, Ohio, built to house the Sanitary Engineering Center of the USPHS was dedicated on April 8, 1954, by the Secretary of the Department of Health, Education and Welfare. The Sanitary Engineering Center, until recently the Environmental Health Center, is the focal point of the Federal Government's research and study into how the health of human beings may be affected by contacts with elements found in air, water, and food, and by radiation and other factors in the environment. The new structure housing the Center is located about 6 mi. east of downtown Cincinnati and overlooking the Little Miami River. It is fairly near the new Little Miami sewage treatment plant serving part of the Cincinnati Metropolitan area.

The building is a six-story reinforced concrete fireproof structure with brick facing. It is approximately 400 ft. by 52 ft. in plan, with special purpose wings on each end. Designed on a functional basis to serve present and proposed future work of the Center, the building is arranged on a modular plan of repeated standard units 12 ft. by 18 ft. in size. Separate air systems are provided for the main building section, the animal quarters, and the laboratory hoods.

The water and waste experimental wing is 3,600 sq. ft. in area and provides space for pilot-plant studies. It is equipped with a 5-ton overhead crane with 37 ft. of head room so that plant equipment may be moved readily. Raw water from the Little Miami River and sewage from the Eastern Avenue interceptor will be pumped into this wing for pilot-scale studies. This wing also contains an auditorium for use in special training programs offered by the Center to state and local health workers.

Other special facilities incorporated in the building include segregated high-level and low-level radiological laboratories; special constant-temperature rooms; centralized distilled-water apparatus (300 g.p.d., piped to each of the laboratory floors); and special instrument rooms housing heavy physical equipment items used in common by the various sections. A second building wing also contains facilities for experimental animal housing and a laboratory trailer shop.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

RECORD AND REPORTING POLICY IN NEW YORK CITY SEWAGE TREATMENT PLANTS *
I. Operation Records

BY F. H. A. LINO

In Charge, Owls Head Plant, Bureau of Sewage Disposal Operations, Department of Public Works, New York City, N. Y.

The problem of developing the various daily log sheets in use at the Owls Head sewage treatment plant of the New York City system was not too easily solved. Both the Operation Section and the Treatment Section, two subdivisions of the Bureau of Sewage Disposal Operations, had submitted several items to be included on the log sheets.

The importance, from an operational viewpoint, of each item suggested, determined whether or not it was to be included on the form. The fact that the log sheets were to be 8½ by 11 in. in size had to be taken into consideration. It finally was decided that nine daily log sheet forms were necessary at this particular plant.

The Weekly Report is common to all the plants and the Monthly Report, with few changes, is similar to those used throughout the system.

Daily Log and Report Forms

Separate log sheet forms were made up for the screening chamber, grit chamber, aeration building, ozone generation, digester building, engine room, pumps and blowers, and main switchboard. All are summarized in the Daily Operation Report.

All the daily log sheets are based on a 24-hr. day, starting at 8 AM. The ozone generation log sheet is on a watch basis and is good for one week. Common to all the forms is the provision of space for entering remarks and for the attendant's signature. If more space is needed for remarks, the reverse side of the form may be used.

Screening and Grit Logs

The simplest of the forms are those used in the screening and grit chambers. Essentially these log sheets, under proper identification, consist of boxes to identify the equipment in operation, the total amount of materials removed from the sewage, and the method of disposal. On the screening log sheet space has been provided for entering sewage temperature for any specified time. On both forms, check marks are used to indicate the equipment in operation for any hour.

Aeration Building Log

On the Aeration Log (Figure 1), the following entries are made on an hourly basis: rate of sewage flow and re-

* Presented at a meeting of the Metropolitan Section, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; March 18, 1953.

turn sludge, air flow, air pressure, and air temperature.

In a separate box, the units in service are checked in. This indicates the number of aerators and final tanks in service and whether sludge from the final tanks is being returned or drawn from the system. Another box is employed for entering data in relation to skimmings removal and disposal. Space is provided for entering the register readings of the air and return sludge meters.

Across the lower portion of the form are spaces for entering, on a watch basis, the excess sludge pump counter

AERATION BUILDING LOG

SD 130

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SEWAGE DISPOSAL OPERATION

OWLS HEAD
SEWAGE TREATMENT WORKS

8 A.M. 19

TIME	SEWAGE FLOW M.G.D.	RETURN SLUDGE M.G.D.	AIR FLOW M.C.F.	AIR PRES. P.S.I.	AIR TEMP °F
9A.M.					
10					
11					
12 N					
1 PM					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12 M					
1 AM					
2					
3					
4					
5					
6					
7					
8					

UNITS IN SERVICE				
	TANK		SLUDGE PUMP	
NO.	AER.	FINAL	RET.	EXC.
1				
2				
3				
4				
5				
6				
7				
8				

SCUM (CONC.)		
COUNTER READING		
PUMP NO	1	2
8 A.M. END		
8 A.M. PREV		
DIFF.		
TOTAL (CU. FT.)		
DISPOSAL TO DIG		
BY TRUCK		

REGISTERS	RET. SLUDGE M.G.D.	AIR FLOW M.C.F.
8 A.M. END		
8 A.M. PREV		
DIFF.		

EXCESS ACT. SLUDGE PUMPS								
COUNTERS	1	2	3	4	5	6	7	8
8 A.M. END								
12 MID.								
4 P.M.								
8 A.M. PREV.								
DIFF.								
TOTAL EX. ACT. SLUDGE				CU. FT.				

SLUDGE BLANKET IN TANK	1	2	3	4	5	6	7	8
8 A.M.								
4 P.M.								
12 MID.								

REMARKS _____

WATCH	ON DUTY	TITLE
1		
2		
3		

AERATION CONDITION			
	D.O.	AER. CYL.	RET. S. CYL.
10 A.M.			
2 P.M.			
6 P.M.			
11 P.M.			
6 A.M.			

FIGURE 1.

readings. Also on a watch basis, sludge blanket readings for each individual final tank are indicated.

Under the heading of "Aeration Condition," a box has been provided for entering, at the stated times, the dissolved oxygen concentration, and the aerated liquor and return sludge cylinder tests.

Ozone Generation Log

The ozone generation station is unique. Many of the numerous gages, meters, and thermometers in the instal-

DIGESTER LOG

SD 132

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SEWAGE DISPOSAL OPERATION

OWLS HEAD
SEWAGE TREATMENT WORKS

DIG NO.	ADDED CU. FT.		WITHDRAWN CU. FT.		DIG. EL. FT.	RECIRC. HRS.	CIRC. WATER REGISTER	TEMP. °F.		
	SLUDGE	SCUM	SLUDGE	DECANT				WATER IN	WATER OUT	DIG.
P 1										
2										
3										
4										
S 1										
2										
3										
4										
TOTAL										

READINGS							
TIME	REGISTERS		GAS STORAGE		SLUDGE STORAGE		
	RAW SLUDGE	DIG. SLUDGE	1000 C. F.	PRES. IN. WATER	TANK 1	TANK 2	CU. FT.
8 A.M.							TO STORAGE
12 MID							
4 P.M.							TO BOAT
8 A.M. PREV.							
DIFF.							

PUMPS									
	TRANSFER					RECIRCULATING			
COUNTERS	1	2	3	4	HRS. USED	1	2	3	4
8 A.M.					TODAY				
8 A.M. PREV.					PREV.				
DIFF.					TOTAL				

GAS PRODUCTION (100 C.F.)								
TIME	P 1	P 2	P 3	P 4	S 1	S 2	S 3	S 4
8 A.M.								
8 A.M. PREV.								
DIFF.								
TOTAL GAS PRODUCED					M.C.F.			

REMARKS

SLUDGE VESSEL			
TIME IN			
TIME OUT			

WATCH	ON DUTY	TITLE
1		
2		
3		

FIGURE 2.

lation were apparently installed so that a careful study of ozone generation could be made. After conferring with the installer of the equipment, it was decided that a proper check on the operation of the equipment could be had by entering, on a watch basis, using check marks in their respective boxes, the unit being reactivated, the unit adsorbing, and the ozone generators in operation. Space is provided for entering the temperatures of the carrier and reactivating airs, and the temperature of the cooling water.

Digester Log

On the Digester Log (Figure 2), are entered all operations relative to the digester operation, sludge storage, and sludge vessel movements.

On a 24-hr. basis, entries are made of the amount of sludge and scum added to each primary digester, the amount of sludge withdrawn, the amount of decant from each secondary digester, digester elevations, sludge recirculation, temperatures of the digester tanks, and temperatures of the digester circulating water.

Under the common heading of readings, on a watch basis, the register readings of the raw and digested sludge meters, gas storage, gas pressure, and sludge storage elevation readings are entered.

Also entered on a 24-hr. basis are the sludge transfer counter readings, the hours of operation of the recirculating pumps, and the register readings of the gas meters.

Space is also provided for entering the sludge vessel movements, listing the name of the vessel and the times of arrival and departure. Boat loadings are indicated in the space provided under the heading "Sludge Storage."

Engine Room Log

As regards the Engine Room Log (Figure 3), if all the gage and temperature readings were to be entered, a sheet approximately 2½ times the prescribed size would have been necessary. To keep the log sheet to the 8½ by 11-in. size, only space for the more important readings was provided.

For each of the six engines, based on taking hourly readings, spaces are provided for entering the temperatures of the jacket cooling water, in and out; the lubricating oil temperature and pressure; and the turbo oil temperature and pressure.

All other instruments are checked visually at the same time that the other readings are entered on the log sheet. Among those visually checked are the pyrometer, manifold pressure, gas pressure, and starting air pressure readings. Provisions also have been made for entering lubricating oil centrifuge operations.

Pump and Blower Log

On the Pump and Blower Log (Figure 4), entries are made on an hourly basis for the sewage flow, the wet well elevation, and the total air output.

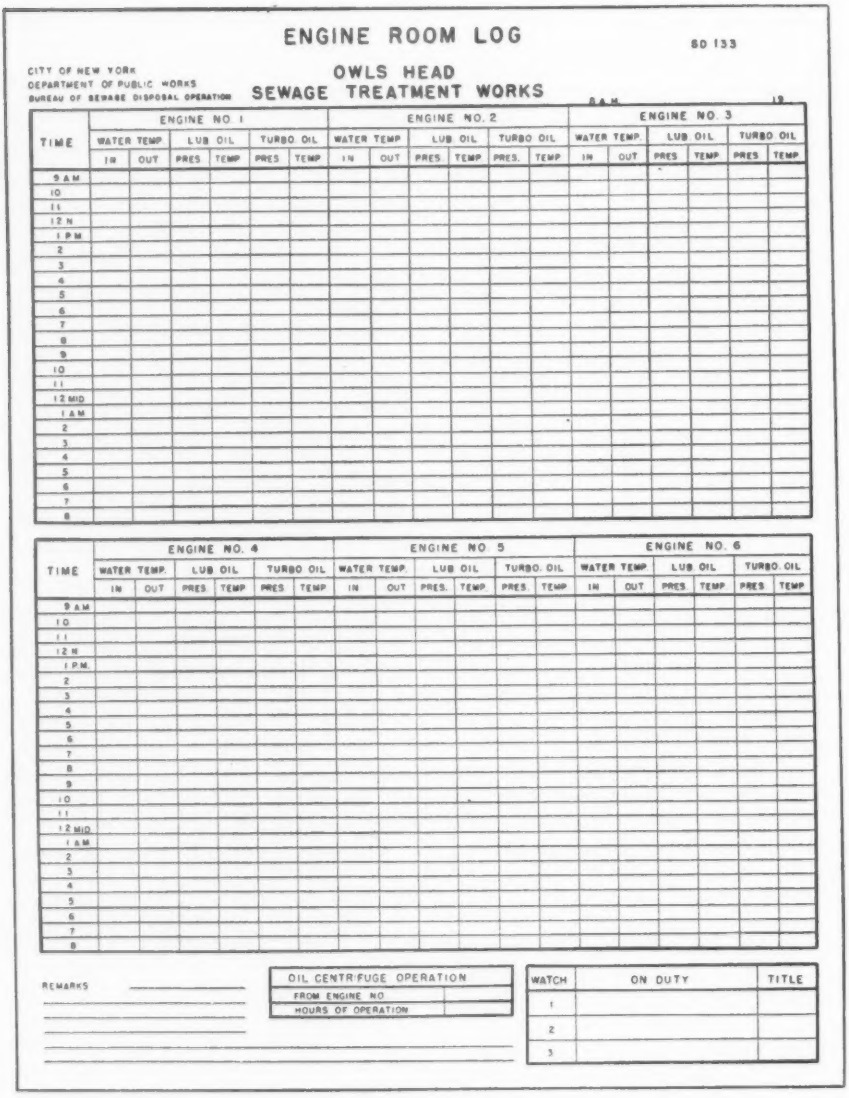
Under the heading of "Main Pumps," for each of the six pumps space has been provided for entering the speed and lubricating oil temperatures of the pumps in operation.

For each of the four blowers, the same provisions have been made for entering the speed, lubricating oil temperature, and the lubricating oil pressure.

Main Switchboard Log

On the Main Switchboard Log (Figure 5), are compiled data relative to the main equipment operation, power generation, fuel consumption, and sewage flow.

On a watch basis, entries are made for the sewage flow, the kilowatt-hours generated for each generating unit, the digester gas used for engines and space heating boilers, and the fuel oil consumption for engines and space heating boilers. Provisions have been made



ENGINE ROOM LOG

SD 133

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SEWAGE DISPOSAL OPERATION

OWLS HEAD
SEWAGE TREATMENT WORKS

A.M. 19

TIME	ENGINE NO. 1						ENGINE NO. 2						ENGINE NO. 3					
	WATER TEMP.		LUB. OIL		TURBO. OIL		WATER TEMP.		LUB. OIL		TURBO. OIL		WATER TEMP.		LUB. OIL		TURBO. OIL	
	IN	OUT	PRES.	TEMP.	PRES.	TEMP.	IN	OUT	PRES.	TEMP.	PRES.	TEMP.	IN	OUT	PRES.	TEMP.	PRES.	TEMP.
9 A.M.																		
10																		
11																		
12 N.																		
1 P.M.																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12 MID.																		
1 A.M.																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		

TIME	ENGINE NO. 4						ENGINE NO. 5						ENGINE NO. 6					
	WATER TEMP.		LUB. OIL		TURBO. OIL		WATER TEMP.		LUB. OIL		TURBO. OIL		WATER TEMP.		LUB. OIL		TURBO. OIL	
	IN	OUT	PRES.	TEMP.	PRES.	TEMP.	IN	OUT	PRES.	TEMP.	PRES.	TEMP.	IN	OUT	PRES.	TEMP.	PRES.	TEMP.
9 A.M.																		
10																		
11																		
12 N.																		
1 P.M.																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12 MID.																		
1 A.M.																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		

REMARKS _____

OIL CENTRIFUGE OPERATION	
FROM ENGINE NO.	
HOURS OF OPERATION	

WATCH	ON DUTY	TITLE
1		
2		
3		

FIGURE 3.

for entering the total of the gas used during each watch.

On a 24-hr. basis, separate entries are made for the power consumption of the main sewage pumps and blowers. The power used by all other equipment, including lighting and transformer losses, is entered under the heading of auxiliaries. Continuing on a daily basis, the hours of operation of the major equipment, including the engines, blowers, and pumps, are entered.

Under the heading of "Totals" are entered the total power generated; the power used by blowers, pumps, and

SD 129

PUMP AND BLOWER LOG

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SEWAGE DISPOSAL OPERATION

OWLS HEAD
SEWAGE TREATMENT WORKS

8 A.M. 19

TIME	SEWAGE FLOW M.G.D.	SEWAGE WET WELL ELEV. FT.	TOTAL AIR C.F.M.	MAIN PUMPS 1 SPEED	1 OIL TEMP	2 SPEED	2 OIL TEMP	3 SPEED	3 OIL TEMP	4 SPEED	4 OIL TEMP	5 SPEED	5 OIL TEMP	6 SPEED	6 OIL TEMP	BLOWERS 1 SPEED	1 OIL PRES	1 OIL TEMP	2 SPEED	2 OIL PRES	2 OIL TEMP	3 SPEED	3 OIL PRES	3 OIL TEMP	4 SPEED	4 OIL PRES	4 OIL TEMP
9 AM																											
10																											
11																											
12 N																											
1 PM																											
2																											
3																											
4																											
5																											
6																											
7																											
8																											
9																											
10																											
11																											
12 MID																											
1 AM																											
2																											
3																											
4																											
5																											
6																											
7																											
8																											

REMARKS _____

WATCH	ON DUTY	TITLE
1		
2		
3		

FIGURE 4.

MAIN SWITCHBOARD LOG

SD 136

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SEWAGE DISPOSAL OPERATION

OWLS HEAD
SEWAGE TREATMENT WORKS

8AM 19

READINGS	SEWAGE FLOW	KWH GENERATED — ENGINE GENERATING UNITS						FUEL USED — GAS - 1000 C.F			OIL - GALS		
	MGD	1	2	3	4	5	6	ENGS	BOILERS	TOTAL	TANK 1	TANK 2	BOILER
8 AM													
12 MID													
4 PM													
8AM PREV													
DIFF													

KWH USED													
8 AM	BLOWERS				PUMPS						AUXILIARIES	
	1	2	3	4	1	2	3	4	5	6	1	2
TODAY												
PREV.												
DIFF.												

HOURS OF OPERATION																	
8AM	ENGINES						BLOWERS				PUMPS					
	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6
TODAY																
PREV.																
DIFF.																

TOTALS		
KWH GENERATED	GAS USED	1000 C.F.
KWH TO BLOWERS	OIL USED - DIESEL	GALS.
KWH TO MAIN SEWAGE PUMPS	OIL USED - NO 6	GALS.
KWH TO AUXILIARIES	SEWAGE FLOW	MGD

REMARKS _____

WATCH	ON DUTY	TITLE
1		
2		
3		

FIGURE 5.

SD 131

DAILY REPORT

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SEWAGE DISPOSAL OPERATION

OWLS HEAD
SEWAGE TREATMENT WORKS

8 A.M. 19

SEWAGE TREATMENT

SEWAGE PUMPED	MG	MAX. RATE	MGD AT	M.	MIN. RATE	MGD AT	M.		
AER. TANKS	MG (+R.S.)	HRS	WEATHER			SUSPENDED SOLIDS	RPM.		
FINAL TANKS	MG	HRS	TEMP. SEWAGE	°F		RAW SEWAGE			
GAL./SQ.FT./DAY			ATMOS. TEMP. MAX.	°F MIN.	°F	FINAL			

AERATION TANKS	SEWAGE FLOW M.G.	RETURN SLUDGE		AIR		SUSPENDED SOLIDS		SLUDGE INDEX
		M.G.	% SEW.	M.C.F.	RATIO	AER.	RET. SLUDGE	

MATERIALS REMOVED FROM SEWAGE

	CU. FT.	WET LBS.	% SOLIDS	DRY LBS.	DISPOSAL
RAKINGS					
GRIT					
SCUM CONC.					
EXCESS A.S.					
TOTAL					

SUSPENDED SOLIDS LOAD DRY TONS × % EFF. DRY TONS RET.

SEWAGE DISINFECTION

CHLORINE ADDED LBS. PER M.G. RESIDUAL P.P.M.

UNITS IN SERVICE

UNIT NO.	ENGINES						MAIN PUMPS						BLOWERS			
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4
HOURS USED																

FUEL USED

	GAS – 1000 C.F.	OIL – GAL.
ENGINES		
BOILERS		
TOTAL USED		
WASTED		
PRODUCED	PER M.G.	

POWER USED

K.W.H.R.		
PUMPS		/M.G.
BLOWERS		/M.C.F.
AUXILIARIES		
GENERATED POWER		/M.G.

OPERATION OF DIGESTERS

DIGESTER NO.	P 1	P 2	P 3	P 4	S 1	S 2	S 3	S 4	TOTAL
SCUM (CONC.) ADDED C.F.									
EXC. ACT. SLUDGE ADDED C.F.									
ADDED LBS. SOLIDS									
ADDED LBS. VOLATILE									
DECANTED C.F.									
DIGESTED SLUDGE DRAWN C.F.									
LBS. SOLIDS REMOVED									
LBS. VOLATILES REMOVED									
TEMP. OF DIGESTER °F									
% SOLIDS DIG. SLUDGE									

TRIPS OF SLUDGE VESSELS

NAME OF VESSEL	TIME		CARGO			
	IN	OUT	CU. FT.	WET TONS	% SOLIDS	DRY TONS

REMARKS

IN CHARGE

FIGURE 6.

auxiliaries; the digester gas used; the fuel oil used; and the sewage flow.

Daily Report

The Daily Report (Figure 6) is a compilation of the information contained in the various forms used within the plant. Its form is such that data relative to sewage treatment, materials removed from the sewage, sewage disinfection, units in service, fuel and power used, operation of digesters, and sludge vessel movements have been sectionalized for ease of entry and in-

terpretation. This makes for an easily readable and concise report, and shows results, ratios, detention, operation, and all other pertinent information immediately.

Other Reports

The Weekly Report, as previously stated, is common to all the plants in the system. On this are entered resumes of power, fuel consumption, the average flow for the period reported, and a listing of equipment out of service. Considerable space has been provided for entering daily remarks.

There are two monthly reports: one is a Monthly Operation Report, the other a Monthly Analytical Report. The Analytical Report is compiled by the chemist in charge of the laboratory and certain calculations made by him are used in compiling the Daily Report, and the Monthly Operation Report. The Monthly Operation Report is a compilation of daily operations. Entries are made on a daily basis, the results being shown both on a daily and a monthly basis.

The daily report, the weekly report and both monthly reports are sent to the Bureau of Sewage Disposal Operations for study and comment.

Comments

Although the difficulties involved in setting a line of demarcation between operational functions and special studies are appreciated, such a separation would be desirable for the sake of simplicity and usefulness of the operation data.

The forms in use at the Owls Head plant were made up long before the plant was put into operation. Nevertheless, they have been found to be adequate in every respect.

II. Laboratory Records

By Robert Shapiro

Chief of Laboratories, Department of Public Works, New York City, N. Y.

New York City has nine operating laboratories, which make the required analyses for ten modern sewage treatment plants and four sewage screening plants. These laboratories function for the benefit of large, complicated, and technical processing procedures.

In an organization of this size, coordination of efforts can only be accomplished by the proper recording of the results obtained from each specialist's efforts so as to properly guide the sequence of operational steps required. In many instances, these records become the only method of contact between the various groups involved in a single over-all objective.

Types of Records

The laboratories keep a variety of records, which may be rather arbitrarily classified according to their different primary functions.

Work Sheets

What may be termed "work sheets" consist of a set of printed forms designed to record the actual analytical working values. For example, one form may show the data for suspended solids analyses, another for B.O.D. analyses, a third for sludge analyses, a fourth for bacteriological work, etc., a separate sheet being used for each day's work. This permits rechecking of computations or miswritten values and other similar human errors. All laboratory data are first recorded in this manner. All other report data are extracted from these work sheets.

Process Control Reports

Another set of forms is used for reporting those analytical values required for immediate use for direct process control. Examples of these are dissolved oxygen values, aerator suspended solids, sludge index values, chlorine residuals, and turbidity values for chemical dosage control. This classification, therefore, is for those data grouped for operational control, the forms being intended for recording and immediately reporting these data to the person responsible for their application. For the larger plants, special forms are prepared to transmit these specific data.

Plant Operation Reports

In all plants, the pertinent figures needed to determine loadings, material removals, and efficiencies are entered from the work sheets onto a Daily Plant Operations Report. This report becomes a joint effort of the plant superintendent and the chemist. At the end of each month, each plant chemist reports all routine analytical data on a large form designed for this purpose. This Monthly Analytical Report becomes the principal record of the plant and is extensively used for study and reference when problems arise in relation to that plant. This form, signed by the chemist at the individual laboratory, is sent directly to the main laboratory office, checked, and then submitted to the Bureau of Operations office for its use.

Special Reports and Records

Every year an extensive survey is made of the harbor waters around New York City. The data are different in many respects from the other laboratory work; therefore, specific forms are used for these work sheets. They are partially filled out by the survey crew and then completed by the laboratory staff. At the end of the season, the required analysis of all data is made and a general report on the over-all picture is submitted to the Chief of the Bureau of Operations.

Industrial waste surveys are made on an area basis before and during the design stage of new plants and for special problems. Here, too, the type of data sought is different from the routine and therefore it is expedient to have special forms for this work and to make one or more summarizing reports to the Bureau office.

Reports of special studies, investigations of complaints, experimental results, and similar work are cleared first through the central laboratory office and then forwarded to the Bureau chief.

Value of Records

The value of such record keeping would almost seem axiomatic. The records are intended, and hopefully expected, to provide the answers to many justifiable questions. The values should determine if the sewage is changing, whether each stage of treatment is effectively performing its functions, and whether the final product measures up to some standard or requirement that has been set for it. The records are important in providing a median from which the significance of variations may be properly judged. They also provide a method of comparison of periods of time with one another, effects of process changes, and comparison of different operations at different plants. The records form a backlog of experience and reference material serving as a basis for design and for progress.

Furthermore, the reports serve as an official record of the compliance of the plant with the requirements of regulatory bodies. The harbor survey report portrays an over-all picture of changes from year to year, industrial wastes surveys check compliance with the City Charter regulations as regards industrial waste discharges, and the experimental reports advance technical understanding and accomplishments.

The engineer completes a task and ends up with some tangible, physical monument to show for his efforts. It might be a road, a tunnel, a pipeline, a building, or a tank. The chemist, however, finishes his year's work and can only display a sheaf of data forms for his efforts. The value of this collected data must, therefore, be persistently stressed, as it is in these recordings that it is hoped others will find data which will aid their progress.

III. Bureau Policy

By Arthur J. Scanlon

Chief of Maintenance and Operation, Bureau of Sewage Disposal Operations, Department of Public Works, New York City, N. Y.

At the New York City sewage treatment plants, the policy has been for many years that adequate records and reports be kept and digested for suitable use. In 1937 the first modern sewage treatment plant in New York City was placed in operation. The policy of adequate records was followed then and is still being carried on with the 10 modern plants in operation in 1953.

Before describing the reporting procedures and records of the Bureau of Sewage Disposal Operations, it is well to give some information concerning the organizational set-up and the responsibilities of the Bureau. The Division of Sewage Disposal of the Department of Public Works is responsible for the design, construction, and operation of intercepting sewers and sewage treatment works for the entire City of New York. Work of the Division is carried out through three major bureaus—Design, Construction, and Operation.

The Bureau of Sewage Disposal Operations is charged with the responsibility of the operation, maintenance, and repair of 10 modern sewage treatment plants having a combined designed capacity of 750 m.g.d., as well as 4 screening plants. In addition, it serves these functions for 4 self-propelled sludge vessels with a total sludge cargo capacity of 215,000 cu. ft. and two sludge barges; 40 mi. of intercepting sewers having 110 regulating chambers and 23 diversion chambers; and power generating facilities of 35 engines having a combined capacity of about 30,000 h.p. and 18 of which are of the dual-fuel type. The cost of maintenance and operation of the delineated plant and facilities is more than $4,000,000 per year and the number of personnel engaged is 735 men. At the end of 1952, the plants were treating some 675 m.g. per day, which is about 65 per cent of all the sewage flow of the city.

In all, there is a total of some 150 forms of records or reports used by the Bureau of Sewage Disposal Operations. Where possible, some forms are common to more than one plant. In general, however, most of the forms are for a particular location or a plant. Most of the completed records are kept at the individual plants, but some are sent directly to the Bureau office, since the report covers activities in more than one plant. Examples of the latter forms are those concerned with the sludge vessel operations and the reports of the maintenance crews of the diesel-gas engines and regulators.

Each plant is required to submit to the Bureau office four reports on operation—namely, a daily, a weekly, and two monthly reports. One of the monthly reports is on operations and the second is on laboratory data.

Daily and Weekly Reports

The daily reports from the plants are similar to those described in the first

paper of this symposium. These reports are reviewed by the Bureau's staff and then placed on file for further reference.

The weekly reports from the plants are integrated into a Bureau's Weekly Report. This report gives the highlights of plant operation, including the average daily flow; the power consumption, whether generated or purchased; the sludge disposal data; major units of operation out of service; and remarks. This report is transmitted to the Division office, to the Bureau of Sewage Disposal Design, to the engineers in charge of sections in the operations office, and to the Chief of Laboratories. The Weekly Report is mainly informative of the status of units of service in the various plants and sludge disposal units and their use.

Monthly Reports

As in most operating units, the period of a month is the real accounting period of all activities of the sewage treatment plants. This is rightly so, since it corresponds with the cost accounting period. Also, a longer period of reporting could possibly result in an accumulation of records for too long a period for effective corrective action to be taken or deficiencies corrected. A review of daily reports can reveal some trends toward bad operation, but placing all the salient data of operation for a month in tabular form makes the trends more obvious and corrective action quicker.

The Bureau of Sewage Disposal Operations prepares a Monthly Report intended to give a composite picture of operations for all the plants. The bulk of the report consists of copies of the Monthly Analytical and Operations Report of the modern sewage treatment plants. There is also given a report of pertinent data concerning the four screening plants. Four summary tables are included, as follows:

1. Monthly totals from all plants—covering flow, power, gas to engines, cubic feet of solids removed from sewage, total dry pounds of solids removed from sewage, and remarks concerning any change from the previous month.
2. Average daily flow in m.g.d., from all plants.
3. Solids removed—average dry pounds of solids removed per day from all plants.
4. B.O.D. removed—average dry pounds of B.O.D. removed per day from all plants.

A chart showing the pounds of solids and B.O.D. removed per day from all the plants for a period of about five years is part of the report.

A review of plant operation is made by the Chief of Maintenance and Operation, giving the average daily flow, the average dry pounds of solids and B.O.D. removed per day from all the plants during the month, and any important comments on the operation of the particular plants. This report, containing some 30-odd pages, is then forwarded to the Division Director and the Design Bureau. Copies are kept at the Operations Office and the headquarters of the Chief of Laboratories. Copies of the Monthly Analytical and Operations Reports of the modern treatment plants are filed at these plants. Thus, the information concerning the monthly operations is distributed to all interested parties.

Value of Records and Reports

Records and reports tell three things: (a) what has been done, (b) what is being done, and (c) what can reasonably be expected in the future. As the years have gone by, many problems and questions concerning operations have been presented in the reports and solved. Some questions still remain, but with adequate records and reports, and studies of these records and reports, they will be answered and improvements made.

HELPS TO PLANT PRESTIGE AND PUBLIC RELATIONS

By George T. Lohmeyer

Superintendent, Sewage Treatment Plant, University of Florida, Gainesville, Fla.

The success of any program depends on an enlightened public opinion. Especially is this true in the field of sewage treatment plant operation, where, by the very nature of the work, cooperation on the part of the public is so necessary. This cooperation, also because of the nature of the work, is at first only reluctantly given, and then usually only as a result of the efforts of the operators themselves to stimulate public interest.

As a starter, every plant must rid itself of such nuisances as odors and gross eyesores. It has been almost axiomatic with sewage plant personnel that "what the eye sees the nose will smell." Cleanliness, then, is of paramount importance, particularly as regards individual tanks, channels, and units, but more especially around grit and screenings chambers, scum troughs and wells, possible pump leakages, etc.

When the primary objective of nuisance removal has been reached as far as is practicable, there are other ways of obtaining improved public relations for the plant and its personnel. Among the most important, from the standpoint of the first impression created on the visitor, is the appearance of the plant grounds. A proper balance of well-kept shrubbery, trees, and grassed areas contributes practical values other than aesthetic. For instance, summer temperatures may be reduced several degrees in the plant.

Buildings and other structures should be kept painted. Piping painted according to a plant color scheme * adds a utilitarian type of plant beauty that is hard to duplicate. If there is any ornamental brass in the plant, a polished surface can be maintained for a much longer period by applying a thin coat of lacquer or by using one of the new plastic sprays.

Adequate first aid kits, gas masks, and fire extinguishers should be on hand and prominently displayed. Neat parts and tool racks do much to create an impression of orderliness, besides keeping tools readily available and encouraging keeping them in good condition. Equipment, aside from being maintained in the best of mechanical condition, should be clean and bright. As time goes on, a printed booklet can be published describing the plant facilities, its organization, and its functions.

Plant-Made Items Help

Various devices that help to explain the plant are easily made. A large flow diagram or map of the plant is a decided help, as are aerial photographs and scale models. A display of pictures taken in the various stages of plant construction often lend added interest. If the plant effluent is sufficiently clear and stable, a small goldfish pond fed with plant effluent provides more proof of the work being done in a plant than any half hour of talking.

All efforts at impressing the public are in vain, however, if the plant personnel do not apply the same kind of attention to themselves. Modern sewage treatment plants have been described by a somewhat poetic operator as being "symphonies in steel and concrete." This might well be true, but slovenly appearing operators wearing disheveled clothes and with uncombed hair can in short order inject a sour note into such a symphony as far as the interested visitor is concerned.

* For a piping identification scheme suggested by the National Safety Council see This Journal, **22**, 5, 699 (May, 1950).

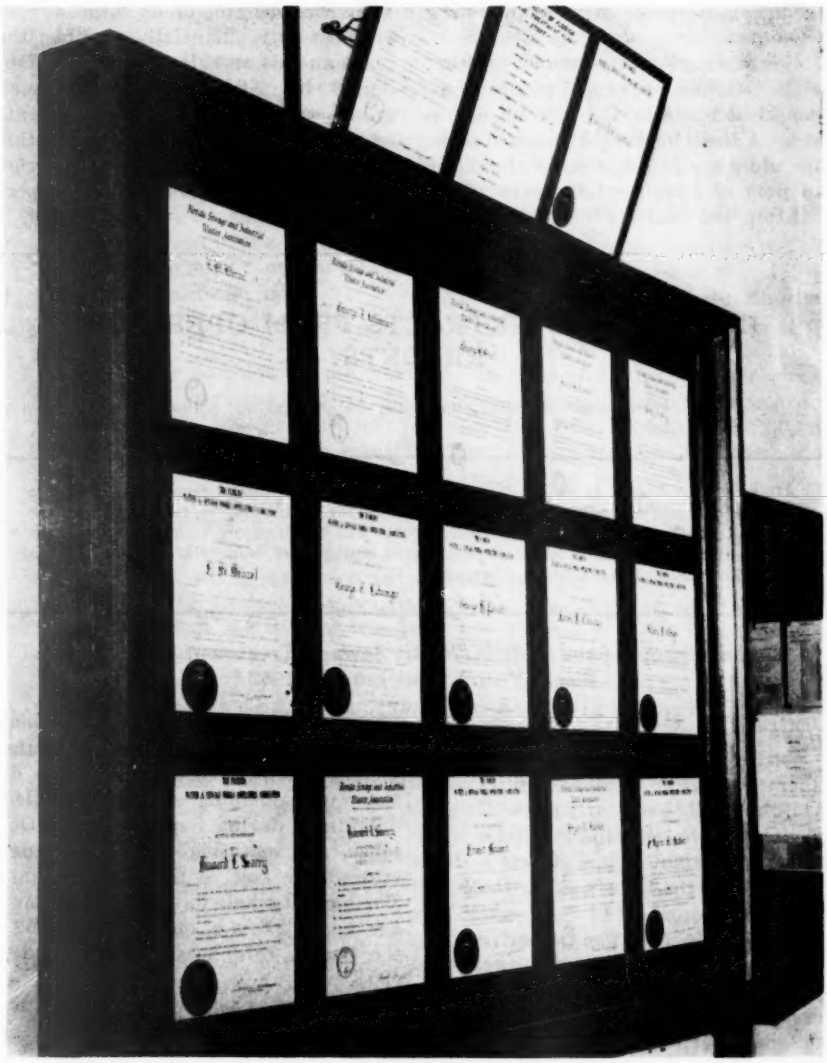


FIGURE 1.—Well-placed certificate and award display board unobtrusively gets across to visitors the interest of the operators in their professional advancement and the pride they take in their plant. Center of three panels above main display board lists entire plant staff, from superintendent to laborers.

When they can be afforded, neat and clean plant uniforms should be worn by operating personnel.

One of the first attitudes needed to be acquired by the operator is the professional attitude toward his work. A certificate display board (Figure 1), on which are mounted certificates, diplomas, operator short course attendance awards, and plant awards, posted in a prominent position in the plant will do much towards achieving this goal and

increasing the prestige of the operating personnel.

Books on plant operation, together with leading sewage publications, should be made available to all operators. A small bookshelf from which the operators are free to borrow should be an item of equipment in every plant.

After the matters mentioned have been attended to, or as large a part of them as is financially possible, the plant and its operation should be publicized by scheduled tours of such groups as high school science students and civic organizations. It is at this point that the generally-accepted versions of public relations begin to operate.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Horse sense is nothing but good stable thinking!—*Anon.*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Detroit, Mich., Sewage Treatment Plant for the Fiscal Year Ended June 30, 1952 *

General

Settled sludge is disposed of by incineration after vacuum filtration. Approximately one-fourth of the sludge is pumped to the single sludge digester. Chlorinated final effluent is discharged into the Detroit River through a diffuser located in 40 ft. of water at a point 400 ft. from the harbor line.

The main pump suction well is pumped down 10 ft. below the normal level twice a week to scour the interceptors of grit and sludge accumulations. Otherwise, it is kept at a fairly high level to reduce the pumping head.

The total pumpage of 153,890 m.g. was 12 m.g., or 8.5 per cent, more than the previous year, due in some measure to the entry of river water into the interceptor over the regulatory dams. Increased industrial activity and home building, greater rainfall, and the use of more refrigeration (air conditioning) equipment, all contributed to the increased flow. To offset this one of the water pumping stations curtailed operations during September and October, and again in June, which decreased the flow to the sewage plant. The highest single day's sewage pumpage was 705.8 m.g. on March 4, 1952; the lowest, 197.6 m.g. on October 28, 1951.

The plant by-pass was not used during the fiscal year to divert raw sewage to the Detroit River.

Grit removal totaled 22,569 wet tons, a 31 per cent increase over that of the previous year. All but 577 tons were incinerated, that amount being sluiced directly to the ash lagoon.

Sedimentation Tanks

The eight primary sedimentation tanks operated normally, with a minimum of shearing of cross collectors

* For last previous extract see THIS JOURNAL, **25**, 1, 99 (Jan., 1953).

due to overloading with sludge during storm periods. The end tanks, Nos. 1 and 8, have always been the critical ones at such times. This year special studies were made to reduce the overloading of cross collectors by stopping the main collectors, thus storing the sludge in the channels until the cross collector could be cleared. This procedure has been quite successful on the two occasions tried and so will warrant further investigation.

Digester

During July and August the empty digester was inspected and cleaned. The scale on the heating coils was removed to allow better heat transfer. Piping changes were made to feed raw sludge more uniformly around the circle. In refilling in September the cover was floated on raw sewage, then seeding sludge which had been saved was added. Gas production was noted seven days after raw sludge was introduced. Foaming was evident for a few days, but subsided when feeding was stopped for 11 days. During this 11-day period gas production increased, then dropped off when feed was resumed. It quickly picked up again and within two weeks was back to normal.

Sludge Filter Building

Sludge solids filtered totaled 48,508 dry tons, a decrease of 1,215 tons from the previous year. Of this total, 60.3 per cent was filtered with ferric chloride and lime, 27.4 per cent with ferrous sulfate and lime, and 3.3 per cent with lime only.

Ferrous sulfate, as spent pickling liquor, is obtained from nearby steel mills. Carbide lime, a waste product of the acetylene gas process, is used in the liquid state a major portion of the time. When carbide lime is not available in sufficient quantities pebble lime is used. One hundred tons of pebble lime are kept on hand as a stand-by supply.

Chemical dosages were higher this year on sludges filtered with ferric chloride and lime, and lower on those with ferrous sulfate and lime. This is largely due to the difficulty of filtering "winter sludge" and the fact that so little of this sludge was filtered with ferrous sulfate.

Sludge Incinerator Building

Two of the incinerators with enlarged breechings (Nos. 2 and 5) are now able to keep up with the normal in-flow of solids. Each is able to burn from 10 to 14 wet tons per hour.

A total of 184,499 wet tons was incinerated, a 5,053-ton increase over the previous year. A total of 9,726 gal. of fuel oil was used—a large part of this for heating and cooling incinerators when going in service or coming off the line.

No. 4 incinerator has been overhauled and is ready for use when needed.

No. 3 incinerator was taken off the line February 19 for overhauling and breeching enlargement after almost six years of continuous use. In rebuilding the hearths in this incinerator castable refractory will again be used, as it has proven suitable for this service in two other units.

Sludge Gas Engine

The 6-cylinder, 350-h.p. gas engine was operated a total of 4,890 hr., or 55 per cent of the time. No gas was available for the engine in July, August, September, and part of October, due to the digester coming back into service.

Chlorination

Chlorination of the final effluent was continued on a round-the-clock basis during the fiscal year. This operation is controlled by the laboratory. Chlorine was applied at a rate of 100 per cent of demand during the warm weather months and dropped to 60 per cent on November 22. The rate was increased to 70 per cent on May 20, and again on June 21 to 80 per cent

TABLE I.—Summary of 1951–2 Operation Data at Detroit, Mich.

Item	Average
Rainfall, total (in.)	36.45
Est. connected pop.	2,600,000
Sewage pumped (m.g.d.)	420.5
Solids removed:	
Grit, total (tons):	
Wet	22,569
Dry	11,056
Volatile	4,073
Sluiced wet	577
Tank scum, total (tons):	
Wet	1,761
Dry	1,148
Volatile	1,034
Susp. solids, total (tons):	
Dry	55,574
Volatile	36,412
Total solids, total (tons):	
Dry	67,778
Volatile	41,519
Analytical data:	
Susp. solids (p.p.m.):	
Influent	184.7
Effluent	100.0
Reduction (%)	45.9
B.O.D. (p.p.m.):	
Influent	124.1
Effluent	79.4
Reduction (%)	36.0
Grit:	
Solids (%)	48.9
Volatile (%)	36.8
Raw sludge to digester:	
Total solids (%)	9.32
Vol. solids (%)	61.12
Sludge digestion:	
Total added (m.g.)	25.02
Dry solids added (tons)	9,919
Total withdrawn (m.g.)	23.29
Dry solids withdrawn (tons)	6,595
Gas produced:	
1,000 cu. ft.	80,650
Cu. ft. per lb. vol. sol. added	6.63
Cu. ft. per lb. vol. sol. cons.	
Supernatant:	
Solids (%)	6.7
Vol. solids (%)	49.3
Sludge filtered:	
Mixed sludge to filters:	
Solids (%)	9.9
Vol. solids (%)	58.8
Total (m.g.)	112.68
Dry solids (tons)	48,509
CaO used (%)*	11.4
CaO used (%)†	11.9
$FeCl_3$ used (%)	0.97
$FeSO_4$ used (%)	1.38
Filter yield (lb./sq. ft./hr.)‡	3.4–4.1
Sludge cake:	
Total solids (%)	35.1
Vol. solids (%)	53.6
Incineration:	
Wet (tons)	184,500
Dry (tons)	68,408
Volatile (tons)	35,227
Wet feed rate (tons/hr./incin.)	9.9
Fuel oil per wet ton burned (gal.)	0.053
Operating expense ($):	
General plant	158,720.57
Pumping station	245,911.27
Rack and grit	47,845.98
Sedimentation	45,185.35
Chlorination	172,795.80
Dig. and elut., net	10,029.54
Filt. and chem.	157,227.00
Incin. and ash	339,781.86
Boiler plant	51,926.02
Dearborn sew. tr.	141,047.15
Intercept. and regul.	4,745.90
San. sew. pump sta.	265,000.00
Misc.	83,057.26
Admin. and gen.	64,299.83
Depreciation	509,720.29
Total	2,297,293.82

* With $FeCl_3$.
† With $FeSO_4$.
‡ Depending on conditioning chemicals used.

of demand. The criterion for these changes was the final effluent coliform index.

The average chlorine demand for the year dropped to 4.95 p.p.m. as compared with 5.91 p.p.m. for the previous year. This is due largely to a continued and effective program of reducing industrial waste discharges into the Detroit sewer system. A total of 505 tons of ferrous sulfate was received at the plant during periods of iron slugs, a 57 per cent reduction from the 1,186 tons received the previous year.

Laboratory

A program of testing and reporting high cyanide sewage slugs was begun this year, using a rapid test developed in the sewage plant laboratory.* This is expected to result in the gradual

* See THIS JOURNAL, **23**, 7, 875 (July, 1951).

elimination of these wastes from the sewer system. Cyanide wastes place a greater demand on chlorine requirements than any other type of industrial discharge with the exception of pickling liquor wastes.

Table I summarizes the 1951–2 operation data.

22nd Annual Report of the Aurora, Ill., Sanitary District Sewage Treatment Plant for the Year 1952 *

By Walter A. Sperry, *Superintendent*

A 4-in. by 4-in. centrifugal pump and motor was installed to circulate the contents of the primary digester. This improvement had long been contemplated. The pump was mounted in the clarifier house on a cantilever walkway and platform that greatly improved the safety conditions, not only for getting at the new pump, but also for servicing one of the primary sludge pumps.

Another major improvement was the complete rearrangement of the gas collecting system for digesters 2 and 3. The meters were removed from the furnace room and placed in the digester control house, with a by-pass arrangement to permit either meter to be removed. A heater system and a common 3-in. gas line conveys the gas to the distribution header in the furnace room. This replaced the two individual 2-in. gas lines and should go a long way toward correcting gas flow interruptions caused by iron sulfide deposits and deterioration of the gas lines by hammering to remove such deposits.

A natural gas pipeline was installed late in the year to bring public utility gas into the plant as auxiliary fuel in lieu of gasoline. It is anticipated that the substitution will result in a 50 to 60 per cent saving in cost of auxiliary fuel, despite the restrictions placed on the use of utility gas for power generation or space heating. The gas can, however, be used for digester heating, for pump engine operation, in the laboratory, and for incinerator operation.

Table II is a summary of the 1952 operating data.

* For last previous extract see This Journal, **25**, 1, 95 (Jan., 1953).

TABLE II.—Summary of 1952 Operation of the Aurora (Ill.) Sanitary District Sewage Treatment Plant

Item	Average	Item	Average
Rainfall (in.)	29.76	B.O.D. (p.p.m.):	
Tributary pop. (estimated)	60,000	Raw	62
Sewage treated (m.g.d.):		Settled	44
Total	8.15	Filter effluent	18
Complete	6.00	Final	13
Primary only	2.15	Reduction (%)	79.0
Screenings (cu. ft. per m.g.)	0.75	Pounds per capita in raw	0.070
Grit (cu. ft. per m.g.)	0.77	Oxygen consumed (p.p.m.):	
Volatile (%)	64.6	Raw	34
Grease and scum (cu. ft./m.g.)	0.48	Settled	29
Suspended solids (p.p.m.):		Filter effluent	24
Raw	168	Final	21
Settled	76	Reduction (%)	38.2
Filter effluent	43	Nitrogen, as NH_3 (p.p.m.):	
Final	26	Raw	7.1
Reduction (%)	84.5	Settled	7.5
Pounds per capita in raw	0.190	Filter effluent	3.2
		Final	2.6

TABLE II.—(Continued)

Item	Average
Nitrogen, as org. N (p.p.m.):	
Raw	17.2
Settled	15.0
Filter effluent	10.5
Final	8.5
Nitrogen, as NO, final eff. (p.p.m.)	6.2
Raw sludge:	
Total solids (%)	5.2
Volatile solids (%)	66.4
Equiv. dry sol. (lb./day)	270
Final settling tank sludge:*	
Total solids (%)	5.2
Volatile solids (%)	55.7
Equiv. dry sol. (lb./day)	18.2
Transfer sludge—1st to 2nd stage:	
Total solids (%)	2.7
Volatile solids (%)	51.5
Equiv. dry sol. (lb./day)	106
Digested sludge:	
Total solids (%)	7.2
Volatile solids (%)	48.3
Supernatant (from 2nd-stage dig.):	
Total solids (%)	0.70
Volatile solids (%)	50.0
Gas production:	
Cu. ft./lb. vol. added	5.67
Cu. ft./lb. vol. destroyed	9.54
Cu. ft./m.g. sewage	4,200
Cu. ft. per capita	0.573
Gas produced in 1st stage (%)	60.8

* To 2nd-stage digesters.

Item	Average
Gas composition:	
CO_2 (% vol.)	31.5
O_2 (% vol.)	0.4
H_2 (% vol.)	2.6
CH_4 (% vol.)	64.6
N_2	0.8
H_2S (p.p.m.)	107
B.t.u. (net)	594
Gas engine earning statement:	
Total engine investment ($)	18,321.50
Net earnings in year ($)	2,431.80
Total net earnings to date ($)	73,850.79
Plant operating costs ($):	
Payroll	43,946.69
Retirement fund	4,738.17
Interceptor system	1,520.97
Truck	127.21
Office	565.50
Laboratory	333.17
New equipment	2,510.04
Repairs	2,384.87
Gas engines	3,910.30
Miscellaneous	3,811.21
Total	63,848.13
Total cost per m.g.	21.41
Total cost per capita	1.064
Total disbursements (operation, interest, bonds, etc. ($):	
Per m.g.	37.27
Per capita	1.852

SIMPLIFIED METHOD FOR DETERMINATION OF OIL IN WASTE WATERS

By Robert E. Beaudoin

Assistant Sanitary Chemist, The Sanitary District of Chicago, Chicago, Ill.

Addition of some eighth grade arithmetic to some common sense recently resulted in what may be a "new" method of oil content analysis, and certainly is a simplified determination.

The laboratories of The Sanitary District of Chicago sometimes receive industrial wastes samples from machine shops and other metalworking establishments. The 1-gal. sample consists of a thick layer of oil mixed with debris, and a water portion, which also is quite dirty. Oil clings to the sides of the bottle and some of the dirt is emulsified in the oil. There is no way of getting a small representative sample and the total 1-gal. sample must be used. The quantity of oil is so large that a good estimate is the best that can be hoped for.

If part of the water is siphoned off, a solvent is added to dissolve the oil, and the solvent layer is separated by means of a separatory funnel, the dirt in the oil is still there and cannot be removed. Some success has been achieved by filtering the oil solvent mixture through glass cloth, but when

there is much dirt this doesn't work too well. Fortunately, the dirt in the oil and solvent settles well enough so that the following method can be used.

Procedure

Siphon off some of the water layer. Do not remove the siphon, as some of the oil clings to the outside of the glass tube. If the siphon is filled with water prior to use, no oil will get into the inside of the tube.

Weigh a suitable wide-mouth fat flask covered with a watch glass. The size of the flask and the amount of solvent used depends on the amount of oil present. A 150- to 300-ml. flask may be used generally.

Fill the flask with solvent and weigh again, being sure to keep the flask covered with the watch glass.

Pour all of the solvent into the 1-gal. bottle, at the same time washing the outside of the siphon and removing it. Tightly stopper the 1-gal. bottle and mix the solvent with the sample by shaking well. Mix so as to remove all the oil from the sides of the bottle.

Allow the bottle to stand, tightly stoppered, for a short time. The solvent with the oil dissolved in it comes to the top and finally becomes quite free of dirt, which settles to the bottom of the solvent layer.

Pipette off a suitable portion (no definite amount) and run into the original weighed flask, being sure to re-cover the flask with the watch glass. Weigh the flask, cover, and contents.

Evaporate the solvent, then weigh the flask, cover, and oil. From this procedure the following quantities are known:

1. Total amount of solvent added.
2. Oil in aliquot.
3. Solvent in aliquot.

The total oil in the sample can be determined from

$$\text{Total oil} = \frac{\text{Total solvent added} \times \text{Oil in aliquot}}{\text{Solvent evaporated from aliquot}}$$

Illustrative Example

The following values are taken from a typical oil determination by the procedure outlined:

Flasks plus total solvent	320.60 g.
Flask	94.03 g.
Total solvent added	218.57 g.
Flask plus aliquot of solvent and oil	127.95 g.
Flask plus aliquot of oil	107.92 g.
Aliquot of oil (107.92 −84.03)	23.89 g.
Solvent in aliquot (127.95− 107.92	20.03 g.

$$\text{Total oil, therefore, } = \frac{218.57 \times 23.89}{20.03}$$

= 260.70 g., or 6.89 per cent on a weight basis.

No doubt the principal of the method described is contained in some old textbooks, but who looks at old textbooks?

TIPS AND QUIPS

"Red Tide" in Aerators

Something new in activated sludge treatment was experienced at the Carbondale, Ill., plant during last summer's heat and dry spell.* One morning Superintendent John Wooten noticed that his final settling tanks were turning pink—color-wise, not politically. In a short time the condition had become so bad that the contents resembled tanks of wine, although no color was detectable in other units.

Microscopic analysis indicated a heavy growth of red protozoa. Positive identification was not made, but it was decided to try chlorine dosing to rid the tanks of the color. Before chlorination could be effected, however, a heavy rain increased sewage flows sufficiently to rid the tanks of the color.

* *The Digester*, 15, 3, 6 (Aug., 1953).

Aluminum "Plating" Paint

A new hard-wearing paint is said to "plate" metal surfaces and withstand temperatures up to 1,200° F. without discoloring or blistering. One-coat application, drying hard in 30 min., fuses with the metal as temperatures are increased. Details are available from Sapolin Paints, Inc., 229 East 42nd St., New York 17, N. Y.

Use With Caution *

Carbon tetrachloride is probably most widely known as a liquid used in some fire extinguishers as a solvent or cleaner. Because of its widespread use in industry and in the home and due to the health hazards involved in its use, many cases of poisoning have resulted. Prolonged, excessive, or repeated exposures to the compound are hazardous and may result in death.

When practical, a less toxic solvent should be substituted for carbon tet. Where it is possible to reduce the vapor concentration to safe levels (less than 50 p.p.m. in air), use of this compound should be discontinued.

Protection should be against skin contact (use special gloves and aprons), inhalation of fumes (use special gas masks or breathing apparatus), and eye damage (use chemical-type safety goggles). *Adequate ventilation is a must.*

Use of carbon tetrachloride extinguishers on fires, particularly in confined spaces, introduces an additional hazard because the heat of the fire not only vaporizes the liquid more readily, but also generates phosgene, an extremely poisonous gas.

Symptoms of carbon tetrachloride poisoning include loss of consciousness, dizziness, mental confusion, nausea. First aid consists of immediate removal from the contaminated atmosphere, calling a physician, artificial respiration if breathing has stopped, and removal of any clothing contaminated with the liquid. If the eyes have been contacted, they should be immediately flushed with large quantities of water. If carbon tetrachloride is swallowed, the person should be made to vomit at least three times.

* Adapted from Booklet I–37, "Guide to Safety When Using Carbon Tetrachloride," published by Association of Casualty and Surety Companies, 60 John St., New York 7, N. Y.

Centrifugal Pump Grease Seal

A unique pump accessory that will interest many operators is the new grease seal shown in Figure 1. The unit consists of an air-tight glass cylinder with plunger. Two copper tubes with fixtures attach the unit to the pump casing and the packing gland housing. Once installed, the unit automatically supplies the shaft packing gland with grease under pressure, preventing rapid wear, leakage, and scoring of the impeller shaft by suspended solids. The manufacturer is Zimmer & Francescon, Moline, Ill.

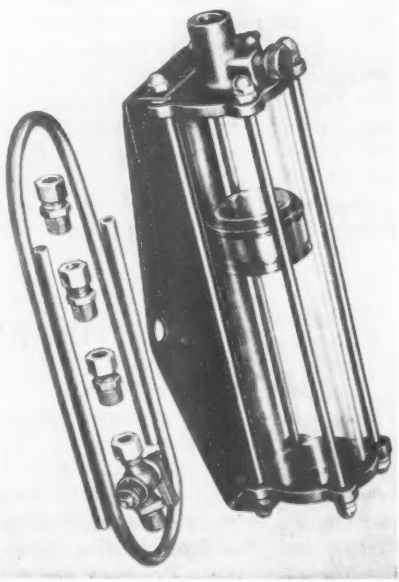


FIGURE 1.—Automatic grease seal for centrifugal pumps utilizes differential pressures in pump casing.

Silver Service from Sewers

In an excellent feature article on the Little Rock (Ark.) sanitary sewer system, and T. Wilson Clapham, manager thereof, the *Arkansas Gazette** gives some of Bill's interesting anecdotes. Perhaps the best of these concerned his promise to give a young friend, planning to marry, a silver service. To fulfill the promise he simply had the sewer cleaning crews turn in all the silverware found in the sewers during the following two weeks, by which time he had enough to fill a shoe box.

Why will some folks so carefully lock the stuff up, then toss it down the drain?

Where To Place Sewers?

An inquiry has been received at Federation headquarters requesting ". . . any information or data concerning the relative merits of installing sanitary sewers in the streets rather than on the rear property lines when there are no alleys available. . . ." The subject seems to be quite controversial, but the paucity of published information on the matter is surprising.

Does anyone have any ideas or experience as to general policy in this matter?

Hatfield Award Competition

Are you working on your plant's annual report to be entered in the Hatfield Award Competition? Remember, the closing date for entries is June 1, 1954. For an outline of requirements see THIS JOURNAL, **25**, 12, 1478 (Dec., 1953); complete rules were published in THIS JOURNAL, **22**, 1, 137 (Jan., 1950).

Industrial Weed Killers

Now appearing under the trade names "Telvar W" and "Telvar DW," two weed killers of the CMU type are claimed to have had wide industrial use with outstanding results during the past two growing seasons. The products are made by E. I. du Pont de Nemours & Company; both are of the substituted urea type.

In each case the "W" indicates that the material is a wettable powder; the "D" indicates that the active ingredient is 3-(3,4-dichlorophenyl)-1, 1-dimethylurea. Both products are designed and packaged for custom applicators and industrial users for application where the objective is complete control of vegetation for an extended period of time.

* Sept. 27, 1953.

Glittering Garbage Grinder

What is claimed to be the most valuable household garbage disposer in the world was given as a 1953 Christmas present to the Leo Ferguson family of Lakewood, Calif., by the Given Mfg. Co. of Los Angeles.

The disposer, a 14-carat gold plated Waste King Pulverator, was originally offered to the Fergusons by the manufacturer several months previously, when they became the 10,000th family to buy a home in Lakewood, a community designed for 100 per cent garbage disposal by home units. The presentation was delayed, however, pending completion of another home being built for the recipients.

Because it was easily the most expensive present they received (estimated cost around $500), the Fergusons placed the gleaming disposer under the family tree until after the holiday season, when it was installed for them without charge. Noting that "people get a gift like this only once in a lifetime," the Fergusons are said to be thinking of removing the doors under the sink so their friends can see that their disposal unit is real gold. After all, why hide such a beautiful—even if utilitarian—thing?

Book Reviews

Pumps—Types, Selection, Installation, Operation and Maintenance. By Frank A. Kristal and F. A. Annett. McGraw-Hill Book Co., New York, N. Y. 373 pp. Price, $6.50 (1953).

This is an extensively revised and rewritten edition of a standard text providing a comprehensive practical study of the available types of pumps covering a wide range of applications. Included are pumps for boiler feed, deep well use, sewage, sludge, chemicals, oil field products, and others. Major additions have been made in the material on diaphragm pumps, rotary pumps, jet pumps, and special pumps for foods.

H. P. Orland

Handbook of Probability and Statistics with Tables. By Richard S. Burington and Donald C. May. Handbook Publishers, Inc., Sandusky, Ohio. 332 pp. Price, $4.50 (1953).

This handbook should prove extremely valuable to those who have occasional or constant use for statistical procedures and probability considerations. It is a convenient summary of theory, working rules, and tabular material useful in practical problems in probability and statistics. It brings together information not otherwise readily available in simple form except by reference to numerous publications.

Readers without detailed statistical training will find this volume a sufficient guide for the more commonly met statistical aspects of their studies. Those with statistical training will find it a convenient summary of the material most often needed.

The book is divided into two main portions. The first part (246 pages) includes a summary of the more important formulas and definitions of elementary statistics and probability theory, making it a valuable review volume. The second part (65 pages) consists of tables of distributions and other quantities of frequent use in statistical work, making it valuable for quick reference, computations, and calculations.

The special indexes of this handbook make it even more valuable to the user. A full page of name index, three pages of symbol index, and a 14-page subject index make it extremely simple to find any particular reference wanted.

H. P. Orland

River Purification. By F. T. K. Pentelow. St. Martin's Press, 103 Park Ave., New York 17, N. Y. 63 pp. Price, $1.25 (1953).

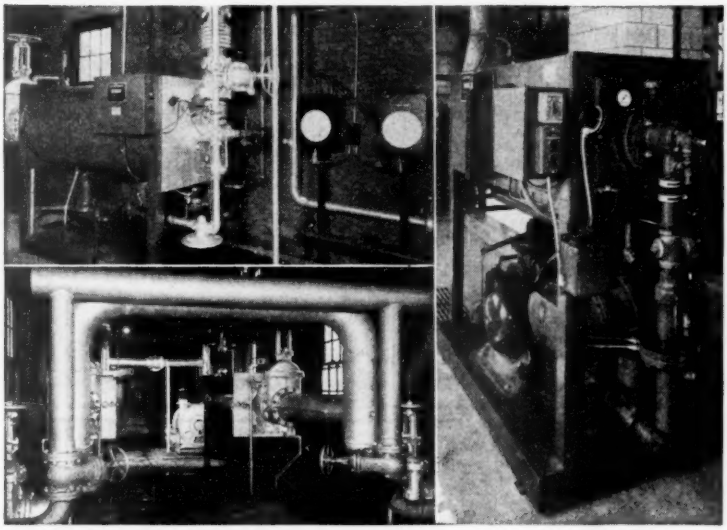
This book contains the three Buckland Lectures for 1952, comprising a legal and scientific review of developments in river purification during the period 1852–1952. The first chapter reviews the development of British river pollution control laws. Chapter II deals with the effects of pollution on streams, stream life, and stream use. Chapter III outlines the history and present status of sewage and wastes treatment. A bibliography of 65 items furnishes excellent background material for the book. Included are 16 entries noting the pertinent Acts of Parliament, ranging from 1847 to 1951. H. P. Orland

Small Sewage Disposal System. By O. J. S. MacDonald. H. K. Lewis & Co., Ltd., London, Eng. 294 pp. (1951).

This book is written with special reference to the tropics from a British viewpoint. It covers construction, practice, background, and design, for latrines and waterborne systems, with a brief discussion of disposal of night soil by composting. The various topics are followed by liberal references, chiefly British, but including U. S. Public Health Service publications. Langdon Pearse

CARBALL UNIT...

SPECIFICALLY DESIGNED FOR THE CLEAN, EFFICIENT CARBONIZATION OF LIQUIDS



- A CO_2 producer that *COMPLETELY* burns GAS or OIL.
- Produces the highest percentage of CO_2 gas with no CO or condensible carbon.
- Completely eliminates oil scum . . . no taste imparted to potable waters.
- No scrubbers or filters required.
- Compressor handles clean, cold air only. The fuel is burned under sufficient pressure to cause deep diffusion directly from the producer.
- Diffuses CO_2 gas by efficient Diffusair system, insuring complete absorption.
- A factory-tested, package unit with air compressor, fuel pumps and appurtenances.
- 50% more chemical efficiency than any other method in current practice.

To Reduce Costs and Modernize Your Plant:

WRITE FOR BULLETIN 7W64

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.

FACTORY • ENGINEERING OFFICES • LABORATORIES

AURORA, ILLINOIS

Proceedings of Member Associations

NEW ENGLAND SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 25th Annual Meeting of the New England Sewage and Industrial Wastes Association was held November 5, 1953, at the Wannamoisett Country Club, East Providence, R. I. A new attendance record was established by the registration of 186 members and guests, plus 18 ladies.

The technical program was divided into two concurrent sessions, one on sewerage and sewage treatment, the other on industrial wastes treatment. The sewage session included the following papers:

"Modern Materials and Methods for Joining Sewer Pipe," by R. B. Seymour, Atlas Mineral Products Co.

"A Scientific Basis for the Liming of Digesters," by Clair N. Sawyer, Professor of Sanitary Chemistry, Massachusetts Institute of Technology.

"Bucklin Point Sewage Treatment Plant Description and Operation," by Clarence V. Hickey, Operating Engineer.

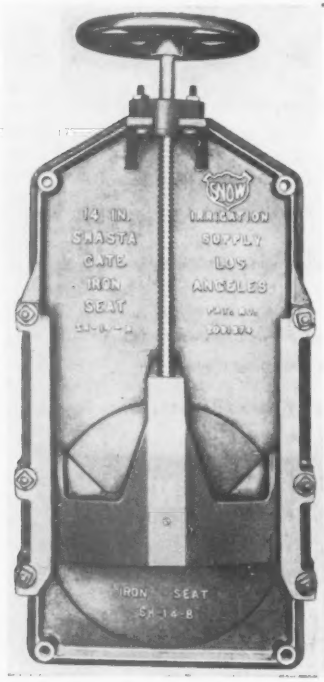
"East Providence Sewage Treatment Plant Description," by John O'Sullivan, Sanitary Engineer.

The industrial wastes session included the following papers:

"Treatment of Wastes at Harnett Tannery," by E. Warren Ward, Partner, Haley and Ward, Ayer, Mass.

"Treatment of Wool Scouring Wastes," by R. E. Briggs, Talbot Wool Combing Co., Norton, Mass.

(*Continued on page 152a*)



SNOW GATES

for

SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

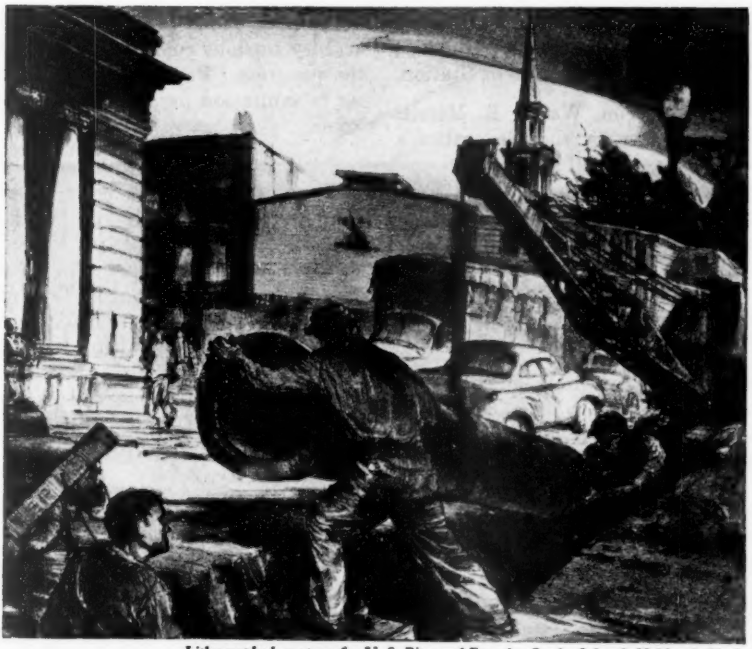
ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

SNOW GATES & VALVES

2437 East 24th Street Los Angeles 54, Calif.



Lithographed on stone for U. S. Pipe and Foundry Co. by John A. Noble, A. N. A.

THIS ILLUSTRATION shows the laying of cast iron pipe in the business section of a small town, which could be for water, gas or sewerage service. Such a situation calls for a pipe with proved long life to be placed beneath the costly permanent pavement. Whether in the business district, residential area or the country, cast iron pipe has established an enviable record of low cost per service year.

We are in an excellent position to furnish your requirements for cast iron pipe, either centrifugally cast in sizes 2- to 24-inch or pit cast for larger sizes—all of which are produced under rigid quality controls and in accordance with standard specifications.

United States Pipe and Foundry Co., General Office, 3300 First Ave., N., Birmingham 2, Ala. • Plants and Sales Offices Throughout the U.S.A.

U.S.
cast iron
PIPE
FOR WATER GAS SEWERAGE AND INDUSTRIAL SERVICE

"Treatment of Flax Cooking Wastes," by Warren H. Oldaker, Lawrence (Mass.) Experiment Station.

At the luncheon, Walter E. Merrill was presented with the Federation's Arthur Sidney Bedell Award.

During the afternoon, tours were conducted through the Bucklin Point sewage treatment plant of the Blackstone Valley Sewer District and the new sewage treatment plant of East Providence.

Officers were elected as follows:

President: C. G. Hammann, Woonsocket, R. I.
1st Vice-President: W. E. Merrill, Boston, Mass.
2nd Vice-President: J. H. L. Giles, Meriden, Conn.
Secretary-Treasurer: S. M. Hurley, Providence, R. I.

STEPHEN M. HURLEY,
Secretary-Treasurer

OKLAHOMA WATER, SEWAGE AND INDUSTRIAL WASTES CONFERENCE

The 1953 Annual Meeting of the Oklahoma Water, Sewage and Industrial Wastes Conference was held November 16–20, 1953, at Oklahoma A. & M. College, Stillwater, Okla., in conjunction with the 27th Water, Sewage and Industrial Wastes Short Course. Registration for the meeting totaled about 185.

Lectures, panel discussions, and laboratory sessions comprised the bulk of the program. Papers of special interest to sanitation personnel were as follows:

"A Preventive Maintenance Program for Water and Sewer Departments," by Grover Morris, Oklahoma City Water Dept.

"Synthetic Detergents—Their Effect on Water and Sewage Treatment Plants," by Russell Culp, Kansas State Board of Health, Lawrence, Kans.

"Some Observation on Wastes Treatment Problems of Sewer Systems," by Ray Lindsey, C. H. Guernsey & Co., Oklahoma City.

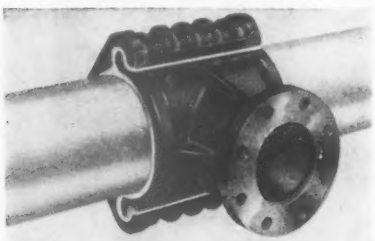
Of particular interest was the separate Industrial Wastes Short Course, held November 19–20, which was devoted almost entirely to forum discussions on industrial wastes problems of research, treatment, and stream standards.

The Federation's Bedell Award was presented to Quintin B. Graves of Stillwater.

Officers were elected as follows:

President: R. E. Cottrell, Newkirk.
Vice-President: M. A. Buercklin, Jr., Oklahoma City.
Secretary-Treasurer: H. J. Darcey, Oklahoma City.

H. J. DARCEY,
Secretary-Treasurer



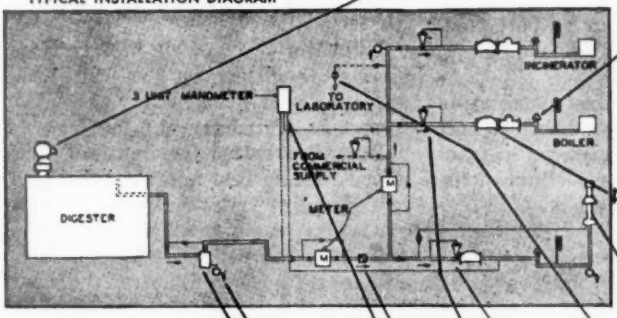
QUALIFIED DEALERS AND DISTRIBUTORS WANTED IN KEY AREAS
Write for full information TODAY!
COREY MFG. CO.

NOW!! the New
BOLTLESS Tapping Sleeves
...for CAST IRON PIPE
...for CEMENT-ASBESTOS PIPE

Top economy in installation and maintenance because NO CAULKING NECESSARY—allows even unskilled workmen to do faster, better installations. LESS EXCAVATION and MORE WORKING AREA through new, simplified mounting process. Assured LIFE OF PIPE SERVICE.

3279 VERDUGO ROAD, DEPT. 26
LOS ANGELES 65, CALIF.

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70—Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check—Fig. 51A or 52A—Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 or 387—Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve—Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer—Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

5-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

Equipment and Supply Lines

Pumps—Bulletin W–52 gives details and specifications on municipal and industrial waste pumps, both portable and stationary.—Marlow Pumps, Ridgewood, N. J.

Conveyor Scale—Instrumentation Data Sheet No. 10.18–3 describes unit systems for weighing material in transit on a belt conveyor.—Minneapolis-Honeywell Co., Philadelphia 44, Pa.

Time Control—A new dial makes possible automatic time control of both long and short operations with only one clock dial.—Tork Clock Co., Inc., Mount Vernon, N. Y.

Chemicals Data—Publ. No. TA–1021–C gives data on chemicals used in water, waste, and sewage treatment.—Wallace & Tiernan, Box 178, Newark 1, N. J.

Concrete Pipe—Special joint protection on reinforced concrete sewer pipe insure against leakage and infiltration.—Universal Concrete Pipe Co., Columbus, Ohio.

Silencers—Two new series of silencers for use on air compressors, blowers, vacuum pumps and other machines expelling high-velocity air to atmosphere are designed to operate at temperatures up to 200° F. under moisture-free air conditions.—Burgess-Manning Co., Libertyville, Ill.

Motor Lubrication—Bulletin 1848 describes and compares various electric motor lubrication methods.—U. S. Electrical Motors, Inc., Box 2058, Los Angeles 54, Calif.

Flow Measurement—Instrumentation for flow measurements in water and waste treatment is discussed in Data Sheet No. 9.6–8.—Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

Dust Collectors—Publ. No. TP–2–M describes new dust collectors for removal of nuisance and toxic dusts raised during hopper loading or other handling or feeding of dry chemicals.—Wallace & Tiernan Co., Inc., 25 Main St., Belleville, N. J.

Incubator—New walk-in incubator gives more shelf space for small floor space.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

Rust Preventive—A light oil that affords lasting rust and corrosion protection even under extreme outdoor conditions is available under the name NO–RUST–OIL.—Octagon Process, Inc., 15 Bank St., Staten Island 1, N. Y.

Vertical Turbine Pumps—Bull. No. W–450–B42 describes and gives specifications for vertical turbine pumps. Although designed primarily for fire protection service, these self-priming pumps appear to be a likely unit for spray irrigation service.—Worthington Corp., Harrison, N. J.

Dry Chemical Feeder—Bull. 50–K57 describes low-rate disc feeder for granular or powdered dry material.—Omega Machine Co., 345 Harris Ave., Providence 1, R. I.

Industrial Products—New edition of the 40-page Industrial Products Catalog gives essential data on insulation, refractory products, asbestos-cement pipe, packings, gaskets, electrical products, frictional materials, roofing, siding, flooring, partitions, and ceilings.—Johns-Manville, 22 East 40th St., New York 16, N. Y.

pH Control—Data Sheet 9.6–5a describes automatic pH control of process liquids by use of dry chemical feeders.—Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

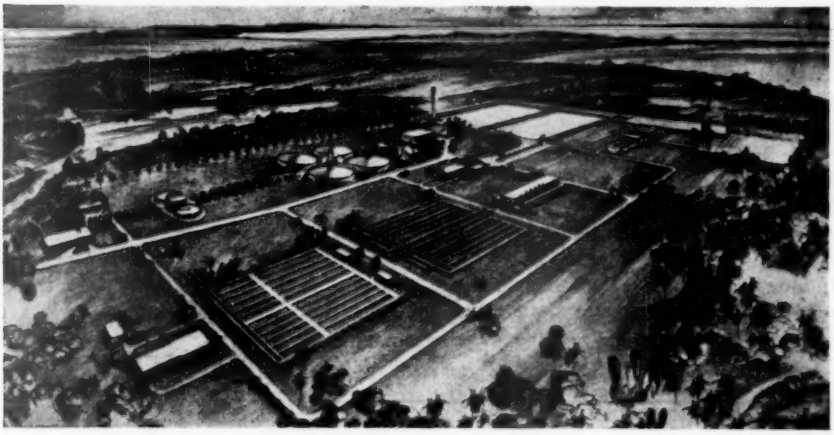
Paint Strippers—Eleven types of paint stripping compounds are described in a new booklet that also gives valuable information on paint stripping.—Octagon Processes, Inc., 15 Bank St., Staten Island 1, N. Y.

(*Continued on page 156a*)

THE LEADER IN SEWAGE SLUDGE DISPOSAL

specified for Miami Project

Two C-E Raymond Incinerators will be used at Miami's new sewage treatment plant, located on Virginia Key, just across Biscayne Bay from Miami proper. Treatment plant design was by Metcalf and Eddy, a member of Miami Sewer Project Associates. Other members are Rader Knappen Tippetts Engineering Co. and Maurice H. Connell & Associates, Inc.



In keeping with the thoroughly modern equipment to be used in this new plant, the filtered sludge will be processed in two C-E Raymond Flash Drying and Incineration Systems. The sludge will be dried from 75% to 8% moisture, and then incinerated to a sterile ash. High-temperature deodorization will eliminate odors from the stack gases. Each C-E Raymond Flash Dryer will process 4½ tons of filter cake per hour, which is equivalent to an evaporation rate per unit of 6,576 pounds.

The system can be easily adapted to the production of fertilizer by the addition of dried sludge handling equipment. This flexibility is just one of the many reasons why the aggregate capacity of C-E Raymond Equipment installed, under construction or on order, is higher than all other heat methods combined.

What has been right for so many other communities will be right for you, too. Let a C-E Raymond specialist demonstrate how efficiently and economically this leading system can end your sludge disposal problems.

B-698A

C-E

COMBUSTION ENGINEERING, Inc.

RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

Western Office: 510 W. Sixth St., Los Angeles 14, Cal. • Eastern Office: 200 Madison Ave., N. Y. 16, N. Y.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

Pipe Jointing Compounds—New booklet contains various reprints on modern methods and materials for jointing sewer pipe.—Atlas Mineral Products Co., Merztown, Pa.

Process Control Instruments—New 20-page Catalog 2 describes process control instruments available at stock points throughout the country.—Fischer & Porter Co., Hatboro, Pa.

Sump Pumps—Bulletin 1029 gives construction details, head and capacity tables, dimensions and other data on turbine-type sump pumps.—Johnston Pump Co., 3272 East Foothill Blvd., Pasadena 19, Calif.

pH Meter—Bulletin 342-92 describes a compact, panel-mounted, automatic pH meter for process control.—Beckman Instruments, Inc., South Pasadena, Calif.

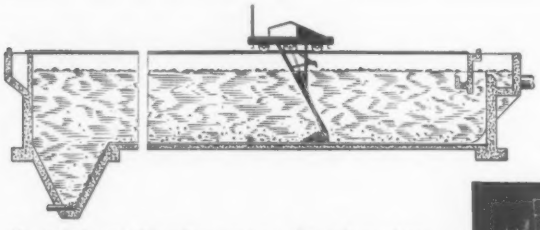
Automatic Proportioner—A new corrosion-resistant automatic proportioning component for chlorinators feeds chlorine to water or sewage lines in direct and preset proportion to the flow rate.—Fischer & Porter Co., Hatboro, Pa.

Rust and Tarnish Removal—New booklet gives instructions on rust and tarnish removal by RUST CLEAN coating.—Octagon Process, Inc., 15 Bank St., Staten Island 1, N. Y.

Liquid Level Controls—New 24-page Bulletin 1160 describes several systems for measuring and controlling liquid level.—Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

Remote Bulb Thermometers—New 44-page Catalog 6709 covers selection data and accessories for remote bulb thermometers and recording apparatus.—Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

Airlock Feeder—New heavy-duty rotary airlock feeder is designed especially to handle finely ground or granular abrasive substances, including chemicals and sludge.—Prater Pulverizer Co., Chicago 50, Ill.

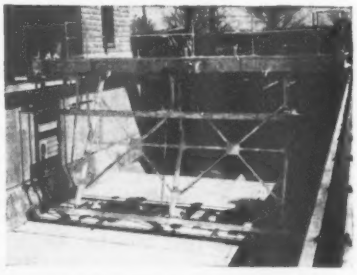


RECTANGULAR CLARIFIERS FOR SEWAGE AND TRADE WASTES

Particularly suitable where space is limited or where sludge delivery is desired at one end of tank. Consists of a bridge crane spanning width of the tank, supporting sludge scraper and skimmer, which moves automatically back and forth.

Many of these units are now operating in sewage plants throughout the country.

This unit has also proven highly successful as an oil-water separator in the treatment of oil refinery waste water. Bulletin 31-D-16.



HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works

New York • Toronto • Chicago • Hibbing • Houston • Salt Lake City • San Francisco

SEND FOR MANUAL 149—MODERN PROCESSES AND EQUIPMENT FOR SEWAGE AND INDUSTRIAL WASTE TREATMENT

BIO-ACTIVATION—exclusive system combines best qualities of trickling filter and activated sludge. *Bulletin 259A.*

MECHANICALLY CLEANED SCREENS—with intermittent automatic control. *Technical Supplement-MS*-Complete Design Data.

GRIT CHANNELS—exclusive Camp Chamber design and Regulator permit easy and instant variations in velocity. *Technical Supplement-CR*-Complete Design Data.

GRIT SETTLERS—with conveyor and exclusive Hydrowash unit which removes grease and organic matter from grit. *Bulletin 249.*

GREASE FLOTATION UNIT—removes grease and oils, oxidizes odors, and aerates by exclusive pretreatment method. *Bulletin 260A.*

SLUDGE COLLECTORS—for rectangular and circular tanks . . . flight type and helicoid cross conveyors, sludge valves. *Bulletin 253A.*

AERATORS—downflow mechanical air diffusion type provides thorough and adjustable oxygenation and circulation of liquor. *Bulletin 265.*

JET AERATION—exclusive method produces an unprecedented rate of oxygen absorption. *Technical data available.*

ROTARY DISTRIBUTORS—reaction and positive drive types with exclusive trouble-free oil seal. *Technical Supplement-RD.*

DOWNFLO FLOCCULATION UNIT—for slow mixing and flocculation of chemicals in sewage treatment processes. *Bulletin 266.*

Send for instructive bulletins listed above

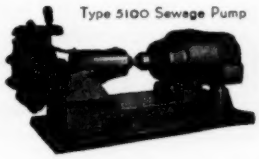
COMPLETE LINE...

Including many Exclusive Developments

Many years of close collaboration in the engineering of municipal and industrial waste treatment plants have enabled us to develop a complete line of installation-tested equipment. Our staff of Sanitary Engineers is exceptionally well qualified to cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

SEWAGE AND SLUDGE PUMPS

American sewage and sludge pumps are unusually strong and rugged in construction. Generous shaft diameter, sturdy bearings, proper bearing span, finest materials, extra metal, careful inspection and testing. *Send for Bulletins.*


Type 5100 Sewage Pump

Inquiries on new installations or improvements on existing plants will receive prompt attention

AMERICAN WELL WORKS

IN OUR 86TH YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago · New York · Cleveland · Cincinnati · Kansas City · Sales Representatives throughout the World

DIRECTORY OF ENGINEERS

(Continued through page 163a)

ALBRIGHT & FRIEL, INC.
FRANCIS S. FRIEL
Consulting Engineers
WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
INDUSTRIAL BUILDINGS
CITY PLANNING VALUATIONS
REPORTS LABORATORY
Suite 1508-18
121 S. Broad St. PHILADELPHIA 7

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick Louis R. Howson
Donald H. Maxwell
Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation
Civic Opera Building Chicago

JOHN J. BAFFA
Consulting Engineer
Sewerage & Sewage Treatment
Industrial Wastes Treatment
Design Plans & Specifications
Investigations & Rate Studies
75 West Street New York 6, N. Y.

MICHAEL BAKER, JR., Inc.
The Baker Engineers
Civil Engineers, Planners, and Surveyors
Municipal Engineers—Airport Design—Sewage Disposal Systems—Water Works Design and Operation—Surveys and Maps—City Planning—Highway Design—Construction Surveys—Pipe Line Surveys
Home Office: Rochester, Pa.
Branch Offices: Jackson, Miss. Harrisburg, Pa.

BAXTER AND WOODMAN
Civil and Sanitary Engineers
Water Supplies Water Treatment
Sewer Systems Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 67 Crystal Lake, Illinois

W. H. & L. D. BETZ
Consulting Engineers
Industrial Waste
Industrial Water
Analysis Design
Investigations Operation
Gillingham & Worth Sts. Philadelphia 24, Pa.

BLACK & VEATCH
Consulting Engineers
SEWAGE - WATER - ELECTRICITY - INDUSTRY
Reports, Design, Supervision of Construction
Investigations, Valuation and Rates
4706 Broadway Kansas City 2, Missouri

CLINTON L. BOGERT ASSOCIATES
Consulting Engineers
CLINTON L. BOGERT IVAN L. BOGERT
J. M. M. GREIG ROBERT A. LINCOLN
DONALD M. DITMARS ARTHUR P. ACKERMAN
Water and Sewage Works
Refuse Disposal Industrial Wastes
Drainage Flood Control
654 Madison Ave., New York 22, N. Y.

CONSULTING ENGINEERS!
If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .
Official Professional Journal of the Sewage and Industrial Wastes Field!

Take advantage of the services of these outstanding consultants!

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal—Industrial Projects
Valuations—Reports—Designs
110 William Street New York 7, N. Y.

BROWN AND BLAUVELT
Consulting Engineers
Water Supply — Airports
Sewer Systems — Highways
Sewage Disposal Plants — Industrial Buildings
Industrial Wastes Problems — Railroads
468 Fourth Avenue New York 16, N. Y.

BUCK, SEIFERT AND JOST
Consulting Engineers
(FORMERLY NICHOLAS S. HILL ASSOCIATES)
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street New York 3, N. Y.

BURGESS & NIPLE
Civil and Sanitary Engineers
Established 1908
Sewage and industrial wastes disposal
Investigations, reports, design, rates
Laboratories, Plant Supervision
2015 W. Fifth Ave. Columbus 12, Ohio

BURNS & McDONNELL
Consulting and Designing Engineers
Kansas City 2, Mo. P.O. Box 7088
Cleveland 14, Ohio 1404 E. 9th St.

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage works field and will afford maximum prestige!

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS — WATER WORKS
Designs and Surveys — Roads and Streets
Planning — Airports
Bridges — Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants–Incineration–Gas Systems
Valuations–Rates–Management
Laboratory–City Planning
210 E. Park Way, Pittsburgh 12, Penna.

CHAS. W. COLE & SON
Engineers ~ Architects
Municipal *Industrial*
Commercial
220 W. LaSalle St., South Bend, Ind.
Phone 4-0127

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
351 East Ohio St. Chicago 11, Ill.

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

It pays to secure competent and experienced engineering advice!

Damon & Foster

Consulting Civil Engineers and Surveyors

Sewerage, Sewage Disposal, Water Supply, Surveys, Land Subdivision, City and Town Planning, Reports, Design, Supervision

Sharon Hill, Pennsylvania

FREDERICK H. DECHANT

ENGINEER

Chairman of the Board, Frederic R. Harris Inc.

Water Works, Industrial Wastes, Sewerage, Recovery Processes, Hydraulic Works, Gas Plants

Philadelphia: Fidelity Phila. Trust Bldg.
New York: 27 William St.

DE LEUW, CATHER & COMPANY

Water Supply — Sewerage
Railroads — Highways
Grade Separation—Bridges—Subways
Local Transportation

Investigations — Reports — Appraisals
Plans and Supervision of Construction

150 North Wacker Drive — Chicago 6
505 Colorado Bldg. — Washington 5

DODGE, BLISS and WALKER

Chemical Engineers

Specialists in Waste Treatment
Surveys and Investigations
Research and Development
Design of Treatment Plants

106 Middle Road — Hamden, Connecticut

CATHODIC PROTECTION

Engineering—Surveys—Design—Installations

Electro Rust-Proofing Corp. (N.J.)

Belleville 9, New Jersey

CONSULTING ENGINEERS!

If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .

Official Professional Journal of the Sewage and Industrial Wastes Field!

FAY, SPOFFORD & THORNDIKE

ENGINEERS

CHARLES M. SPOFFORD — RALPH W. HORNE
JOHN AYER — WILLIAM L. HYLAND
BION A. BOWMAN — FRANK L. LINCOLN
CARROLL A. FARWELL — HOWARD J. WILLIAMS

Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment
Airports—Bridges—Turnpikes
Port and Terminal Works—Industrial Bldgs.

BOSTON — NEW YORK

FINKBEINER, PETTIS & STROUT

CARLETON S. FINKBEINER — CHARLES E. PETTIS
HAROLD K. STROUT

Consulting Engineers

Reports, Designs, Supervision,
Water Supply, Water Treatment, Sewerage,
Sewage Treatment, Wastes Treatment,
Valuations & Appraisals

518 Jefferson Avenue — Toledo 4, Ohio

FREESE, NICHOLS AND TURNER

Consulting Engineers

2111 C & I Life Building
Houston 2, Texas
CH-1624

FROMHERZ ENGINEERS

Structural - Civil - Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Industrial Waste Disposal

Investigations; Reports; Plans and Specifications; Supervision

823 1/2 Poydras St. — New Orleans, La.

EDWARD A. FULTON

Consulting Engineers

Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control

3299 Brown Road — Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.

ENGINEERS

Dams, Water Works, Sewage, Industrial Wastes & Garbage Disposal, Highways, Bridges & Airports, Traffic & Parking—Appraisals, Investigations & Reports.

HARRISBURG, PENNA.

Branch Offices: Pittsburgh, Pa. Philadelphia, Pa. Daytona Beach, Fla. Pleasantville, N. J. Chesapeake, W. Va.

Take advantage of the services of these outstanding consultants!

GILBERT ASSOCIATES, INC.
Engineers and Consultants
Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
Investigations and Reports
New York 607 Washington St. Washington
Houston READING, PA. Philadelphia

GLACE AND GLACE
Consulting Sanitary Engineers
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal
Design, Construction and Supervision of Operation
1001 N. Front Street Harrisburg, Pa.

GREELEY & HANSEN
Engineers
Samuel A. Greeley — Paul Hansen (1920-1944)
Paul E. Langdon — Kenneth V. Hill
Thomas M. Niles — Samuel M. Clarke
Water Supply, Water Purification
Sewerage, Sewage Treatment
Flood Control, Drainage, Refuse Disposal
220 S. State Street, Chicago 4

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage works field and will afford maximum prestige!

HASKINS, RIDDLE & SHARP
Consulting Engineers
Water — Sewage
Industrial Wastes
Refuse — Hydraulics
1009 Baltimore Ave. Kansas City 5, Mo.

HAVENS AND EMERSON
W. L. Havens — C. A. Emerson
A. A. Burger — F. C. Tolles — F. W. Jones
W. L. Leach — H. H. Moseley — J. W. Avery
F. S. Palocsay — E. S. Ordway
Consulting Engineers
Water, Sewerage, Garbage, Industrial Wastes, Valuations—Laboratories
Leader Bldg. Cleveland 14, O. — Woolworth Bldg. New York 7, N. Y.

HAZEN AND SAWYER
ENGINEERS
Richard Hazen — Alfred W. Sawyer
Municipal and Industrial Water Supply
Purification and Distribution
Sewage Works and Waste Disposal
Investigations, Design,
Supervision of Construction and Operation
110 East 42nd Street New York 17, N. Y.

HENNINGSON, DURHAM & RICHARDSON, INC.
Consulting Engineers since 1917 for more than 600 cities and towns
Water Works, Light and Power, Sewers, Sewage Treatment, Reports, Flood Control, Appraisals, Drainage
Standard Oil Bldg. Omaha 2, Nebraska

HORNER & SHIFRIN
Consulting Engineers
W. W. Horner — E. E. Bloss
H. Shifrin — V. C. Lischer
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

JONES, HENRY & WILLIAMS
(Formerly Jones, Henry & Schoonmaker)
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. Toledo 4, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, N. Y. FT. LAUDERDALE, FLA.

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design, Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

It pays to secure competent and experienced engineering advice!

MORRIS KNOWLES Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1313 Park Bldg. Pittsburgh 22, Pa.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street Rochester, 4, N. Y.

GEORGE B. MEBUS
Consulting Engineer
Water Supply Sewage Treatment
Industrial Waste Treatment
NORTHWESTERN NATIONAL BANK BUILDING
GLENSIDE, PA

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
Airfields
Statler Building
Boston 16

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers
SEWAGE TREATMENT—WATER SUPPLY
INCINERATION—DRAINAGE
INDUSTRIAL WASTE TREATMENT
APPRAISALS
827 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

PAN AMERICAN CONSULTANTS
Engineers
River & Harbor Development—Hydroelectric Power—Dams—Ports—Flood Control
Irrigation—Reclamation—Airports—Water Supply—Sewage & Industrial Waste Treatment
Reports—Consultation—Design
Midland Building, 176 West Adams St., Chicago 3, Ill.

PARSONS, BRINCKERHOFF HALL & MACDONALD
G. Gale Dixon, Associate
Civil and Sanitary Engineers
Water, Sewage, Drainage and Industrial Waste Problems.
Structures — Power — Transportation
51 Broadway New York 6, N.Y.

CONSULTING ENGINEERS!
If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .
Official Professional Journal of the Sewage and Industrial Wastes Field!

PIATT AND DAVIS
WM. M. PIATT P. D. DAVIS
Consulting, Designing, and Supervising Engineers
Water Works, Sanitary Sewers, Water Purification
Sewage Treatment, Public Buildings, Streets
Power Plants, Electrical Distribution
Reports and Appraisals
One Eleven Corcoran St. Bldg. Durham, N. C.

MALCOLM PIRNIE ENGINEERS
Civil and Sanitary Engineers
Malcolm Pirnie Ernest W. Whitlock
Robert D. Mitchell Carl A. Arenander
Malcolm Pirnie, Jr.
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 West 43rd Street New York 36, N. Y.

LEE T. PURCELL
Consulting Engineer
Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes, Investigations & Reports; Design; Supervision of Construction & Operation
Analytical Laboratories
86 De Grasse St. Paterson 1, N. J.

THOMAS M. RIDDICK
Consulting Engineers and Chemists
Municipal and Industrial Water Purification, Sewage Treatment Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses
369 E. 149th St. New York 55, N.Y.

Take advantage of the services of these outstanding consultants!

RIPPLE AND HOWE
Consulting Engineers
O. J. Ripple B. V. Howe
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants. Refuse Disposal, Airports.
833-35 Twenty-Third St. Denver 5, Colorado

RUSSELL AND AXON
Consulting Engineers
Civil — Sanitary — Structural
Industrial — Electrical
Rate Investigations
408 Olive St. Municipal Airport
St. Louis 2, Mo. Daytona Beach, Fla.

SMITH and GILLESPIE
Consulting Engineers
All types of
Municipal Public Works &
Utilities
Complete Services
P. O. Box 1048, Jacksonville, Fla.

STANLEY ENGINEERING COMPANY
Sewerage—Waterworks
Drainage—Flood Control
Electric Power—Airports
Hershey Building
Muscatine, Ia.

ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports
109 S. High St. Columbus 15, Ohio

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

J. STEPHEN WATKINS
J. S. Watkins G. R. Watkins
CONSULTING ENGINEERS
Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.
251 East High Street Lexington, Kentucky
Branch Office
901 Hoffman Building Louisville, Kentucky

WERTZ ENGINEERING CO., Inc.
CONSULTANTS, DESIGNERS & CONSTRUCTORS
Water Supply & Purification
Sewage & Industrial Waste Treatment
Stream Pollution Studies
Chemical & Bact. Laboratory Service
441 North 2nd St. Reading, Pa.

WESTCOTT & MAPES, Inc.
Engineers
VALUATIONS—STUDIES—REPORTS
DESIGN—SUPERVISION
Industrial Waste Problems
Utilities—Industrial Plants
Commercial Buildings—Institutions
Public Works
New Haven, Connecticut

WESTON & SAMPSON
Consulting Engineers
Water Supply, Water Purification, Corrosion Control
Sewerage, Sewage and Industrial Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN & HOWARD
Engineers (Est. 1869)
Sewerage, Sewage Disposal, Municipal and Industrial Development Problems, Water Supply, Water Purification, Water Front Improvements, Investigations, Reports, Designs, Supervision, Valuations
89 Broad Street, Boston, Mass.

WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

It pays to secure competent and experienced engineering advice!

ELYRIA, OHIO Also SAVES MONEY WITH "Flexibles"

Like most typical cities which are careful with the taxpayers' money, Elyria, Ohio, chose "Flexible" equipment. Pictured is their modern "Flexible" SeweRoder which takes 9/10ths of the usual hard work out of cleaning sewers – works faster and permits "preventative maintenance" to be carried on due to low cost of operation – without interference by the weather. (Some cities report cleaning sewers for less than 2¢ per foot.) Seen in the picture from left to right are Walt Decker and John Hovis of the city council, Henry Ault, Mayor, Ralph Terry, Safety-Service Director, Art of the sewer crew, and George Carrick, Superintendent. This city knows that "Flexibles" are based on careful study of the problem, and that "Flexible" stands behind every sale – as it has for 20 years.

Write for our **FREE** *Catalog*

Flexible SALES CORPORATION

3786 Durango Ave., Los Angeles 34,

(DISTRIBUTORS IN PRINCIPAL CITIES)

AMERICA'S LARGEST LINE OF PIPE CLEANING TOOLS AND EQUIPMENT

INDEX TO ADVERTISERS

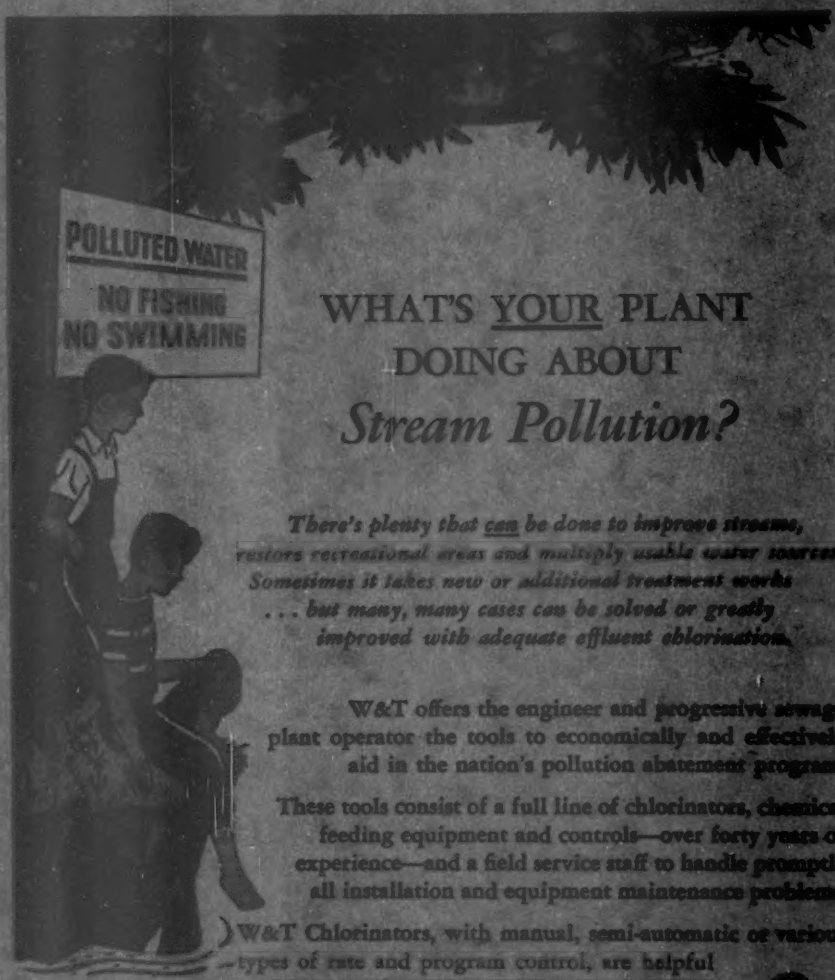
	Page
American Brass Company, The	139a
American Car and Foundry Company	137a
American Well Works	157a
Builders-Providence, Incorporated	127a
Cast Iron Pipe Research Association	132a, 133a
Chain Belt Company	138a
Chicago Pump Company	125a
Combustion Engineering, Incorporated (Flash Dryer Division)	155a
Corey Manufacturing Company	152a
Dorr Company, The	148a
Fairbanks, Morse and Company	136a
Flexible Sales Corporation	164a
General Chemical Division (Allied Chemical and Dye Corp.)	142a
Hardinge Company, Incorporated	156a
Inertol Company, Incorporated	141a
Infilco Incorporated	144a
Link-Belt Company	135a
Morse Boulger Destructor Company	143a
Morse Brothers Machinery Company	134a
Nichols Engineering and Research Corporation	145a
Pacific Flush Tank Company	146a
Rockwell Manufacturing (Nordstrom Valve Division)	140a
Simplex Valve and Meter Company	129a
Snow Gates and Valves	150a
United States Pipe and Foundry Company	151a
Vapor Recovery Systems Company	153a
Walker Process Equipment, Incorporated	149a
Wallace and Tiernan Company, Incorporated	Back Cover
Yeomans Brothers Company	131a

DIRECTORY OF ENGINEERS, pp. 158a–163a

Albright & Friel, Inc.
Alvord, Burdick & Howson
Baffa, John J.
Baker, Michael, Jr., Inc.
Baxter & Woodman
Betz, W. H. & L. D.
Black & Veatch
Bogert, Clinton L., Associates
Bowe, Albertson & Associates
Brown & Blauvelt
Buck, Seifert & Jost
Burgess & Niple
Burns & McDonnell
Camp, Dresser & McKee
Capitol Engineering Corp.
Chester Engineers, The
Cole, Chas. W., & Son
Consoer, Townsend & Associates
Damon & Foster
Dechant, Frederick R.
De Leuw, Cather & Company
Dodge, Bliss & Walker
Electro Rust-Proofing Corp. (N. J.)
Fay, Spofford & Thorndike
Finkbeiner, Pettis & Strout
Freese, Nichols & Turner
Fromhers Engineers
Fulton, Edward A.
Gannett Fleming Corddry & Carpenter, Inc.
Gilbert Associates, Inc.
Glace and Glace
Greeley & Hansen
Haskins, Riddle & Sharp
Havens and Emerson
Hazen & Sawyer
Hennington, Durham & Richardson, Inc.
Horner & Shifrin
Jones, Henry & Williams
Kelz & Holroyd
Kennedy, Clyde C.
Knowles, Morris, Inc.
Lozier, Wm. S., Company
Mebus, George B.
Metcalf & Eddy
Nussbaumer, Clarke & Velzy, Inc.
Pan American Consultants
Parsons, Brinckerhoff, Hall & Macdonald
Platt & Davis
Pirnie, Malcolm, Engineers
Purcell, Lee T.
Riddick, Thomas M.
Ripple & Howe
Russell & Axon
Smith & Gillespie
Stanley Engineering Company
Stilson, Alden E., & Associates
Watkins J. Stephen
Wertz Engineering Company, Inc.
Westcott and Mapes, Inc.
Weston & Sampson
Whitman & Howard
Whitman, Requardt & Associates

PATRONIZE OUR ADVERTISERS—whose support makes possible the publication of this journal. *When writing advertisers be sure to mention SEWAGE AND INDUSTRIAL WASTES.*

LANCASTER PRESS, INC., LANCASTER, PA.



WHAT'S YOUR PLANT DOING ABOUT *Stream Pollution?*

There's plenty that can be done to improve streams, restore recreational areas and multiply usable water sources. Sometimes it takes new or additional treatment works . . . but many, many cases can be solved or greatly improved with adequate effluent chlorination.

W&T offers the engineer and progressive sewage plant operator the tools to economically and effectively aid in the nation's pollution abatement program.

These tools consist of a full line of chlorinators, chemical feeding equipment and controls—over forty years of experience—and a field service staff to handle promptly all installation and equipment maintenance problems.

W&T Chlorinators, with manual, semi-automatic or various types of rate and program control, are helpful in many other plant problems, too—such as grease removal, filter ponding prevention and septicity reduction, to mention just a few.

Why not start your community on the road to clean streams? Your W&T Representative will be glad to help, without obligation, of course.

WALLACE & TIERNAN

25 MAIN ST. BELLEVILLE 9, N. J.